AD-A244 652

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MASS HUMAN DELOUSING SPRAY GUN

FINAL REPORT

JOHN BURKE

SEPTEMBER 16, 1991

Supported by

U.S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND
Fort Detrick, Frederick, Maryland 21702-5012

Contract No. DAMD17-91-C-1084

Cardinal Scientific, Inc.
7594 Commerce Lane
Clinton, Maryland 20735

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)

2. REPORT DATE
September 16, 1991

3. REPORT TYPE AND DATES COVERED
Final 1 Apr 91 - 1 Sep 91

4. TITLE AND SUBTITLE
Mass Human Delousing Spray Gun

5. FUNDING NUMBERS
DAMD17-91-C-1084
62787A
3M162787A870 AV
DA335855

6. AUTHOR(S)
John Burke

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Cardinal Scientific, Inc.
7594 Commerce Lane
Clinton, Maryland 20735

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Medical Research & Development Command
Fort Detrick
Frederick, Maryland 21702-5012

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

An advanced prototype mass human delousing spray gun was developed from (1) evaluation of current system, (2) pediculicide flow property testing, and (3) volumetric metering device design and testing. The prototype gun meters 2.7 ±.4 grams consistently. Exhibits no leakage or jamming; and reduces operator fatigue due to trigger actuation by an order of magnitude. The prototype gun can be completely disassembled for maintenance and O-ring seal replacement. Recommendations for the production gun configuration include reduced hopper size for 1.8 gram dosages, reduced weight via alternative material, internal cartridge valves, internal air passages, encapsulated cylinders, ruggedized handle and relocated air supply fitting.

14. SUBJECT TERMS
Human Mass Delousing, Pediculicide, Malathion, Pneumatic, Metering

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

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( ) In conducting research utilizing recombinant DNA technology, the investigator(s) adhered to current guidelines promulgated by the National Institutes of Health.

[signature] 9/16/91

PI Signature Date

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I. Introduction and Background

The purpose of this research was to develop a detailed design and advanced prototype of a mass human delousing spray gun. Design goals for the gun included improved reliability, improved human factors and maintenance procedures.

The objectives of the research were: (a) uniform and regulated pediculicide dust dispersal, (b) elimination of jamming, (c) prevention of leakage during operation, and (d) reduction of operator fatigue.

The research was accomplished by the following method: (1) evaluation of existing equipment, (2) test and evaluation of pediculicide flow characteristics, (3) prototype design and testing of volumetric metering devices, and (4) integration and testing of actuation devices, meter and reservoir into an advanced prototype.

II. Administrative Information

The referenced contract became effective on 3 April 1991. CSI acknowledged the appointment letter designating the Contracting Officer's Representative (Mickey Anderson) by letter dated 23 April 1991. Flow characteristic testing by Jenike & Johanson was performed during the first week of May. Mr. Brosky and Mr. Burke travelled for 2 days (May 16 & 17) to the Jenike & Johanson, N. Ballerica, MA facility to review the bulk solids test results of the 5 lbs sample of DOUSE pediculicide. Mr. Mickey Anderson and Mr. George Brown conducted a site visit on June 26; at which time a tour and progress review were held. Attending progress review for Cardinal Scientific were Mr. Brosky, Mr. Martinez and Mr. Burke.

III. Evaluation of Existing Equipment

In the wake of substance control and limited human exposure, a system which precisely meters pediculicide dust is required. The current generation of delousing equipment was developed by the U.S. Army Biomedical Research and Development Laboratory (USABRDL). See appendix A for historical background. The system consists of a regulating manifold (30 psig) and six self-actuating dispersal guns. The manifold pressure can be supplied by a Military Standard engine and Military Standard compressor, a truck air brake connection, or any air supply of sufficient flow (4 scfm). However, as indicated by the Army low supply pressures can result in regulator pressures as low as 25 psig.

The guns have a local pediculicide reservoir mounted on the nozzle gun. The reservoir canister is made of transparent polypropylene to visually detect refill. Just below the reservoir a volumetric metering drum is gravity fed through an oval orifice hopper. An adjustable mesh screen at the bottom of the hopper provides the path for pressurized air. A manual trigger actuation partially revolves the drum to disperse the powder under pressure (Darby et al,1988). The gun is a cast, welded assembly with a narrow, flexible metal dispersal nozzle for applying the powder below clothing.

The gun has been proven in laboratory testing and field application to effectively meter 1.8 ±0.23g of carrier dust (Darby et al, 1987) . However, the spray gun possesses several disadvantages from a reliability and user interface standpoint (see figure 1). Mass-delousing operations require rapid and multiple actuation. The gun's lever has no mechanical advantage. Actuation is effected by squeezing the lever with the fourth and fifth fingers. These fingers are the weakest, resulting in rapid hand and forearm fatigue.

The gun's reservoir must be held vertical to assist gravity feed of the hopper. For example, if the gun is rolled to access the sleeve cuff or tilted forward to spray down the upper back, the pediculicide will shift in the reservoir resulting in a possible incomplete dosage. The reservoir is closed from atmospheric pressure; relying on air leakage from the drum to agitate/aerate the pediculicide powder. Often a user must shake or otherwise manually agitate the canister to effect hopper fill.

During development, the meter drum and casing tolerances were tightened; resulting in repeated binding. Although the drum fit was loosened, the polymer drum suffers from static friction at the extreme retraction of the hand lever linkage. Powder will build up in the drum runout, where it can be blown out by leaking air or remain to resist drum rotation. The small bypass port to the drum radius, a self cleaning feature of the gun, becomes clogged during use or misaligned during assembly. Another characteristic which contributes to dust build-up is the rapid decrease in cross sectional area from the hopper to the dispersal nozzle. Due to a combination of factors (i.e. poor nozzle reduction and inadequate air hole placement) all the powder is not fluidized at dispersal.

Poor tooling or improper manufacturing tolerances have led to large variance in assemblies and performance. Consequently, dust build up in the mechanism leads to repeated jamming and leakage which significantly reduces the guns performance and overall delousing capability. Regular cleaning and maintenance could minimize powder build-up; however, the handle linkage pin is press fit into the drum from one side only. As a result, the guns cannot be completely disassembled for maintenance or servicing.

DISADVANTAGES/PROBLEMS

① RAPID OPERATOR FATIGUE
② INCOMPLETE FILL; LIMITED TO VERTICAL ORIENTATION
③ DRUM BINDING & LEAKAGE
④ CANNOT BE DISASSEMBLED FOR REGULAR MAINTENANCE OR REPAIR

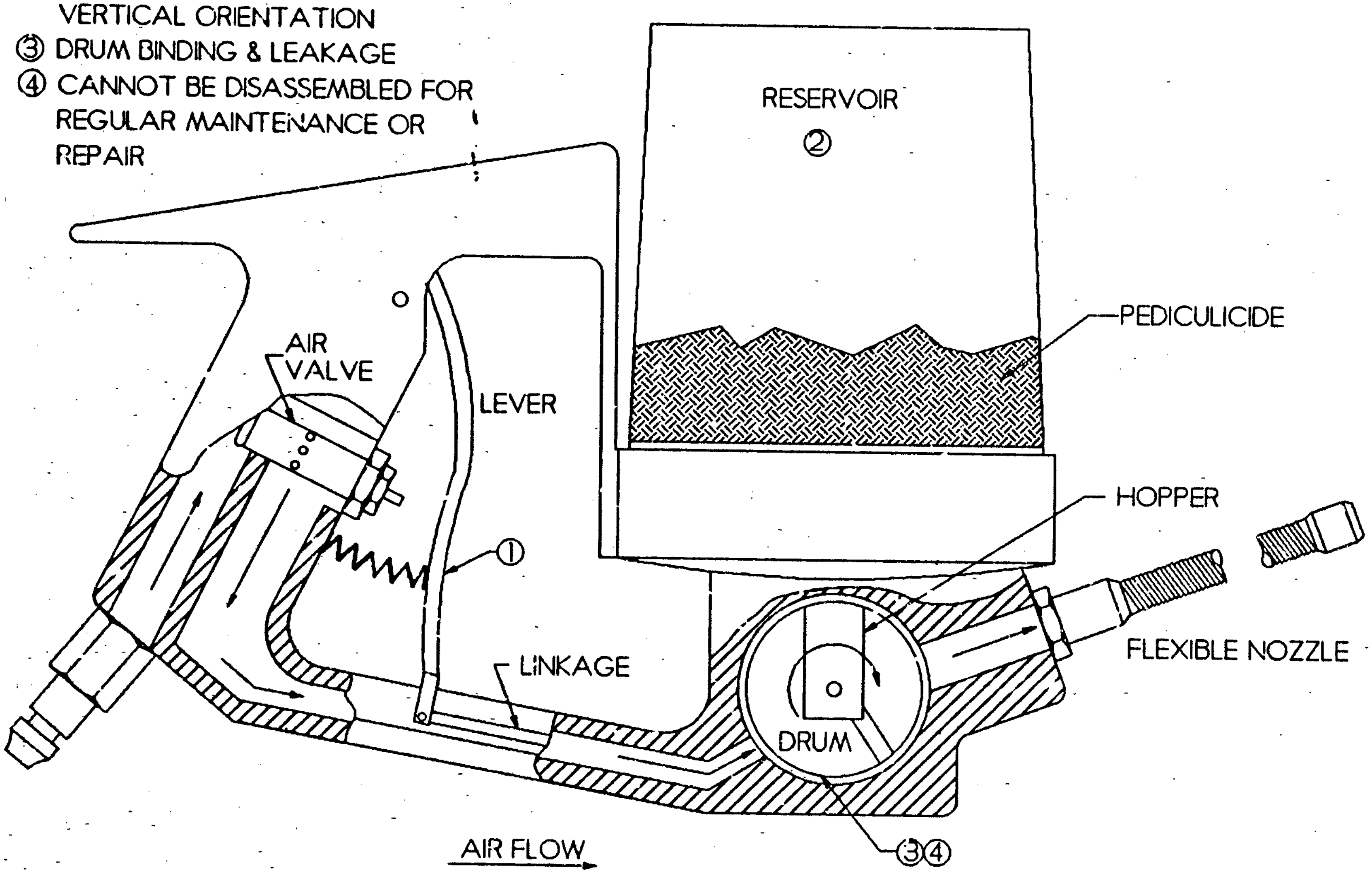


FIGURE 1- MASS DELOUSING SPRAY GUN

The current gun weighs approximately 950 grams or 2.1 lbs (empty). The current reservoir has a volumetric capacity of approximately 500 cc or 300 grams of 1% malathion pediculicide; yielding a full unit weight of 1250 grams or 2.8 lbs. At a total dosage of 30 grams, the 500 cc capacity equates to delousing 10 individual subjects before refill is required.

The spring force, a major contributor to operator fatigue, required to actuate the current gun is approximately 10.5 lbs. This force does not consider trigger valve force for stem travel nor actuator friction or binding. Any gun design, desiring volumetric batch metering, will require the following sequence: (1) fill the hopper in proximity to the reservoir, (2) actuate or move the hopper to the nozzle, (3) dispense the hopper content out the nozzle, and (4) return the hopper to the reservoir for refilling.

Below is a table of quantified mechanical performance criteria of the current gun.

Total number of guns per regulator	6	
Air pressure	30	psig
Volumetric flow per gun	4	scfm
Maximum weight per gun (empty)	2	lbs
Reservoir Capacity	500	cc
Batch Volume (2 grams)	3.3	cc
Actuation force (manual)	>10.5	lbs

IV. Pediculicide Dust Flow Characteristics

The current pediculicide formulation (DOUSE, see Appendix A) was tested for flow characteristics under diverse operating conditions (temperature and humidity). The flow characteristics provided the criteria for several conceptual meter/reservoir designs which accurately disperse the pediculicide dosage. Impetus for bulk solids characteristic testing is provided by a variety of industries, such as mining, food packaging, powder packaging, and chemical manufactures. In these industries continuous feeding of bulk solids is mandatory for efficient production. Flow characteristic testing provides the configuration and method by which the bulk solid is stored and fed. Ideally, flow testing yields the bin geometry which yields consistent gravity feed via funnel-flow, mass- flow or expanded flow. If a bin or reservoir is improperly dimensioned for the material, flow can be halted due to arching or ratholing (see figure 2). Pediculicide flow into the hopper has been predominantly incumbered by arching.

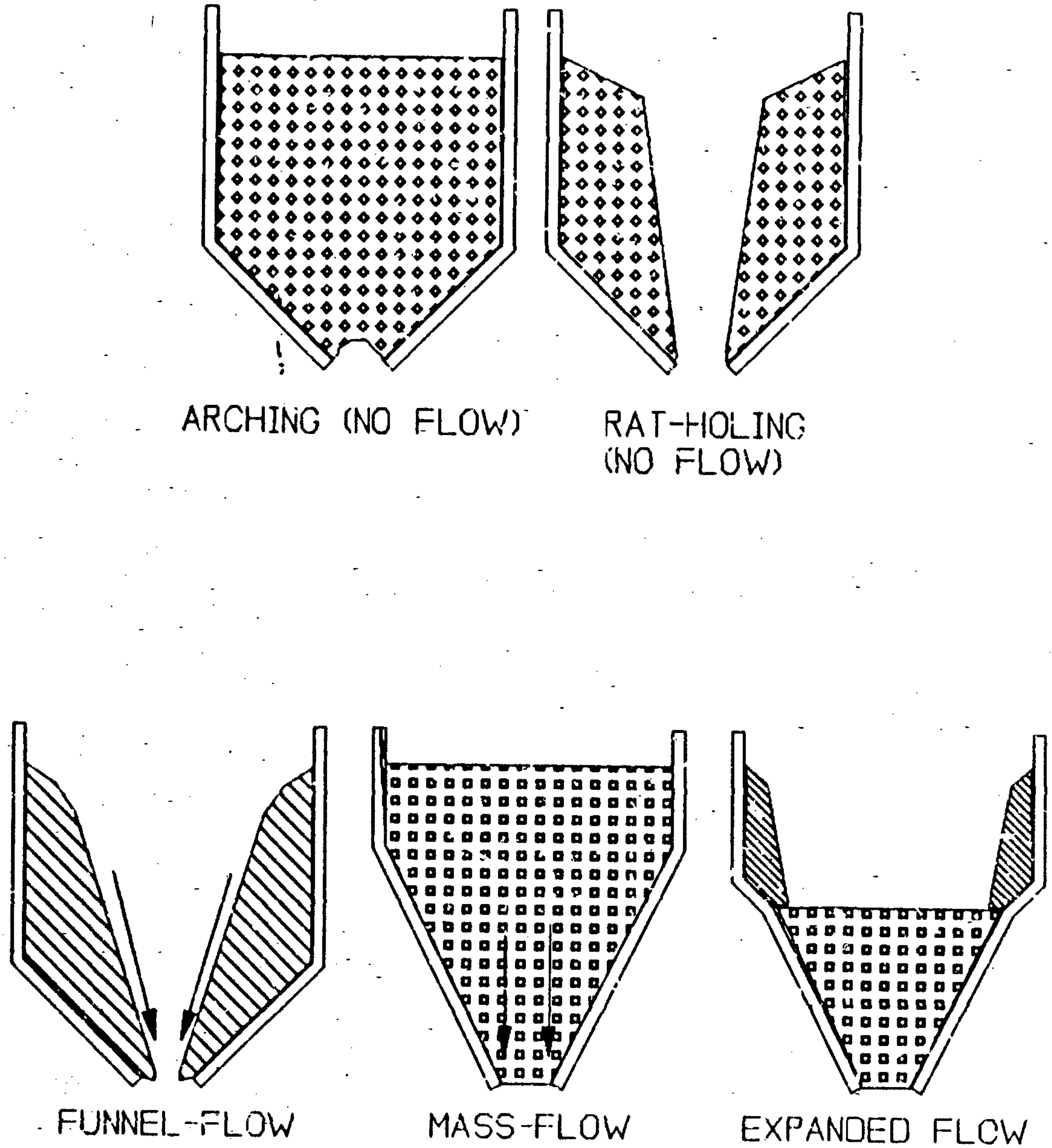


FIG. 2. FLOW CHARACTERISTICS.

The pediculicide formulation is Malathion Premium Grade 1% dust (fine powder); consisting of 1% Malathion, approximately 97.5% Pyrophyllite carrier/diluent, 1% Odorant, and .5% Anticaking agent. Classification of bulk solids range from coarse to fine to powdered. Powder exhibits a free flow function of less than 2, which characterizes a cohesive and non-free flowing substance; a powder factor of 95-100%, relatively low flowability range of 5 to 25 and a floodability range of 0 to 20. Several factors can influence the flow characteristics of the pediculicide dust, such as, temperature and humidity.

A 5 lbs (approximately 1 gallon) of pediculicide dust was subjected to the following tests: moisture content, bulk density, bin dimensions, hopper angles, flow rate and permeability. Several of the tests were conducted at elevated temperatures (72°F, 90°F and 110°F); temperature had little or no effect. See Appendix B for the full detailed report.

The bulk density test measures the density of the solid at various levels of compaction. Minimum bulk density (aerated, well stirred) was 33.1 lbs/ft^3. This compares to previous density measurements by hand of 37.7 lbs/ft^3. The material is very compressible which has significant impact on our ability to volumetrically meter the solid. However, since the bin or container volume (500ml) is sufficiently small to neglect head compaction, accurate volumetric metering can be achieved by consistent stir and/or aeration.

Bin dimension and wall angle to achieve mass flow through a hopper are large (1.3 ft and steep 11 degrees). Consequently, the slight funnel angle of the previous design provided little or no benefit; however some bottom angle may be retained for structural purposes. Since these dimensions (1.3 ft dia. & 11°) cannot be achieved within the envelope of the spray gun, the bin must have the capability to actively stir (agitate) the dust maintaining consistent density while forcing the metered volume into the hopper. The agitation approach is referred to as a live bottom.

The permeability of the dust is low due to its compressibility. The permeability effects the supply air's ability to lift and fluidize the dust for flow and dispensing down the nozzle. Again, poor permeability can be overcome with consistent agitation and adequate blow nozzle fluidization.

In summary, the flow characteristic testing indicate that the dimensions required for the dust to gravity feed into the hopper are impractical for a hand held gun. The gun must actively agitate or place the metered amount, since gravity can not be relied on for continuous hopper feed. Additional recommendations to achieve accurate and consistent metering include a slightly divergent hopper chamber, oval chamber orifice with a 3 to 1 length to width ratio, and several jets or ports to achieve complete fluidization

of the chamber powder when dispensing. Comments indicated the chamber seal, to prevent leakage and jamming, would present the most challenging design problem.

V. Volumetric Metering Devices

The majority of the research focussed on the development of a reliable meter/reservoir system which readily integrates with the actuator and nozzle system. Several candidate metering concepts were designed and breadboarded; including the shuttle valve (figure 3), the sliding membrane (figure 4), the rotary vacuum fill system (figure 5), and the vertical membrane (figure 6).

Seal Design

Common to each of the four initial meter designs is the O-ring seal. Several packing and wiper seal configurations were investigated; however, the O-ring was selected for reliability and availability. During meter development and testing, several o-ring materials were evaluated. The most common material, Buna-Nitrile rubber, and abrasion resistent polyurethane O-rings were tried. Based on design tolerances and subsequently O-ring compression, the ring presents friction drag resisting actuation. In an effort to reduce friction, Teflon and Teflon encapsulated Silicone O-rings were also evaluated.

To properly apply the O-ring seal, several recommendations should be met. The rubbing speed between O-ring and sealed surface should be kept low. O-ring compression should be achieved between the groove and seal surface. For dynamic applications, such as the dust metering, no moving parts should contact. Only the O-ring should contact the sliding surface. The primary cause of O-ring failure is extrusion into the clearance between the moving parts, usually caused by excessive fluid pressure. For the meter, pressures are not great; however, the O-rings are susceptible to abrasion as they travel over ports in the adjacent sliding surface. The ports allow the o-rings to momentarily expand. As travel reaches the opposite rim of the port, the O-ring must be shoved or recompressed. The O-ring could catch and abrade; diminishing seal capacity. All ports were chamfered to assist recompression.

Meter Evaluation

Industrial process feeders employ several devices, often in tandem, to maintain consistent bulk solids flow of powders. These devices include the augers, single screw feeder, twin-screw feeders, rotary feeders, belt feeders, vibratory feeders, disk or table feeders, and vane or slat feeders. Several of these devices were evaluated for mass human delousing application (Burke & Brosky, 1990). These devices require electrical power, providing unlimited sources of agitation and feed. Beyond an adaptation

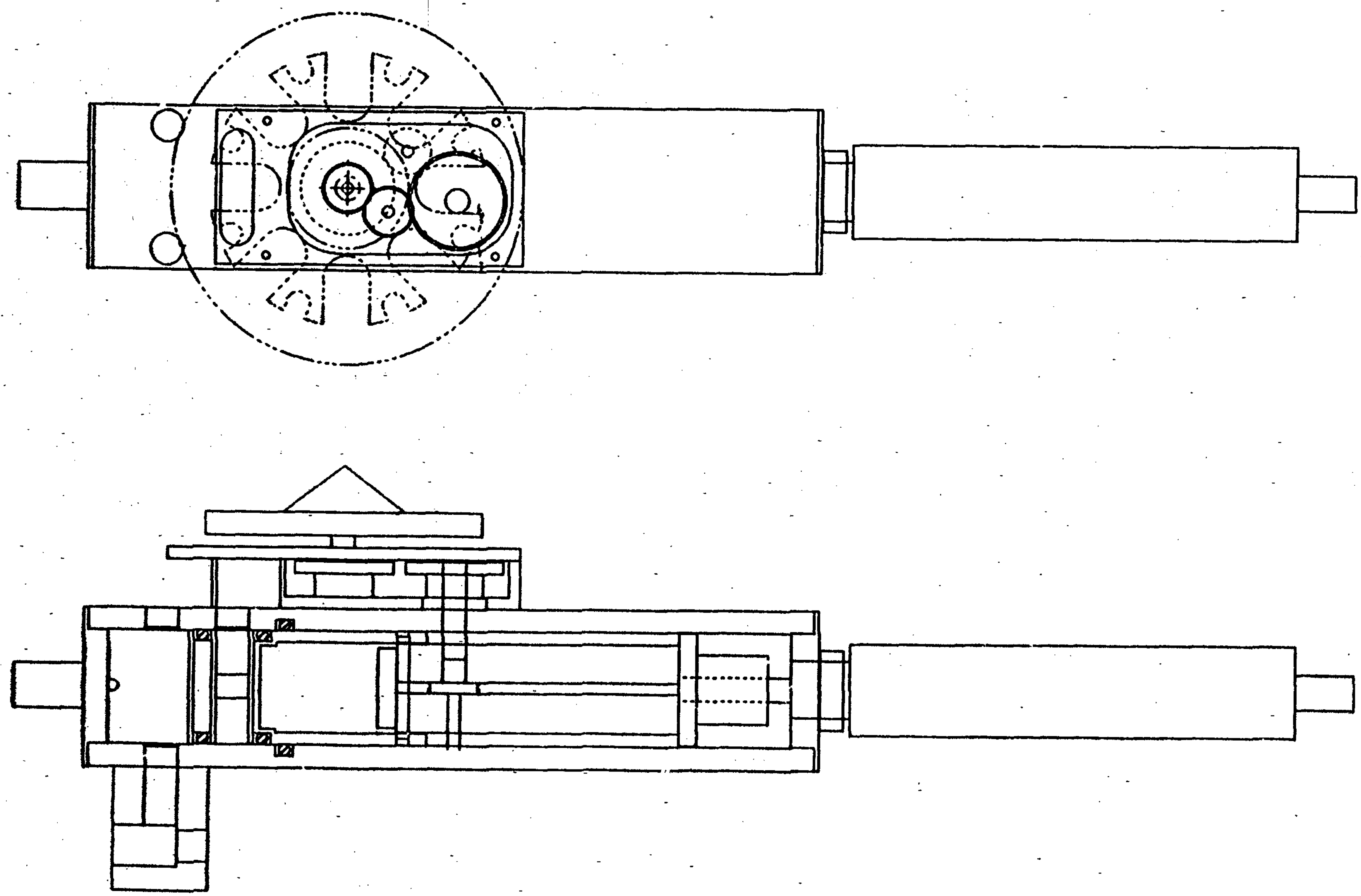


FIGURE 3 SHUTTLE VALVE DESIGN

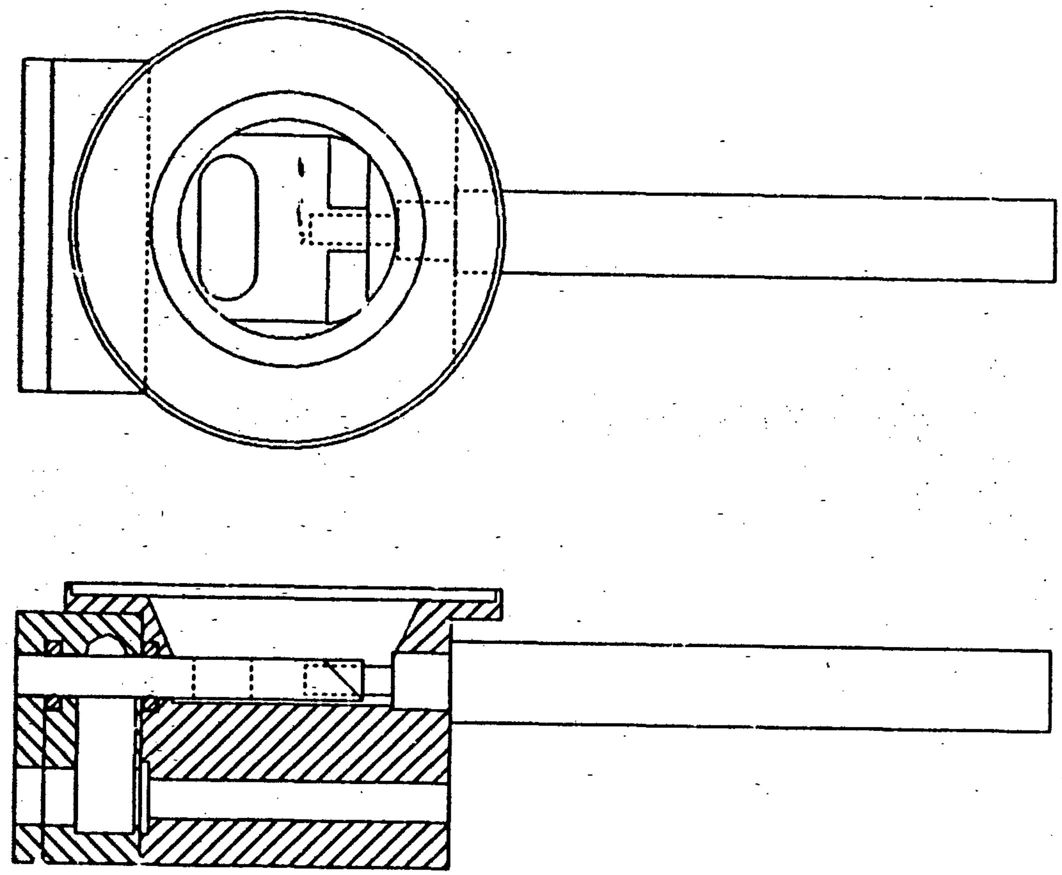


FIGURE 4 SLIDING MEMBRANE DESIGN

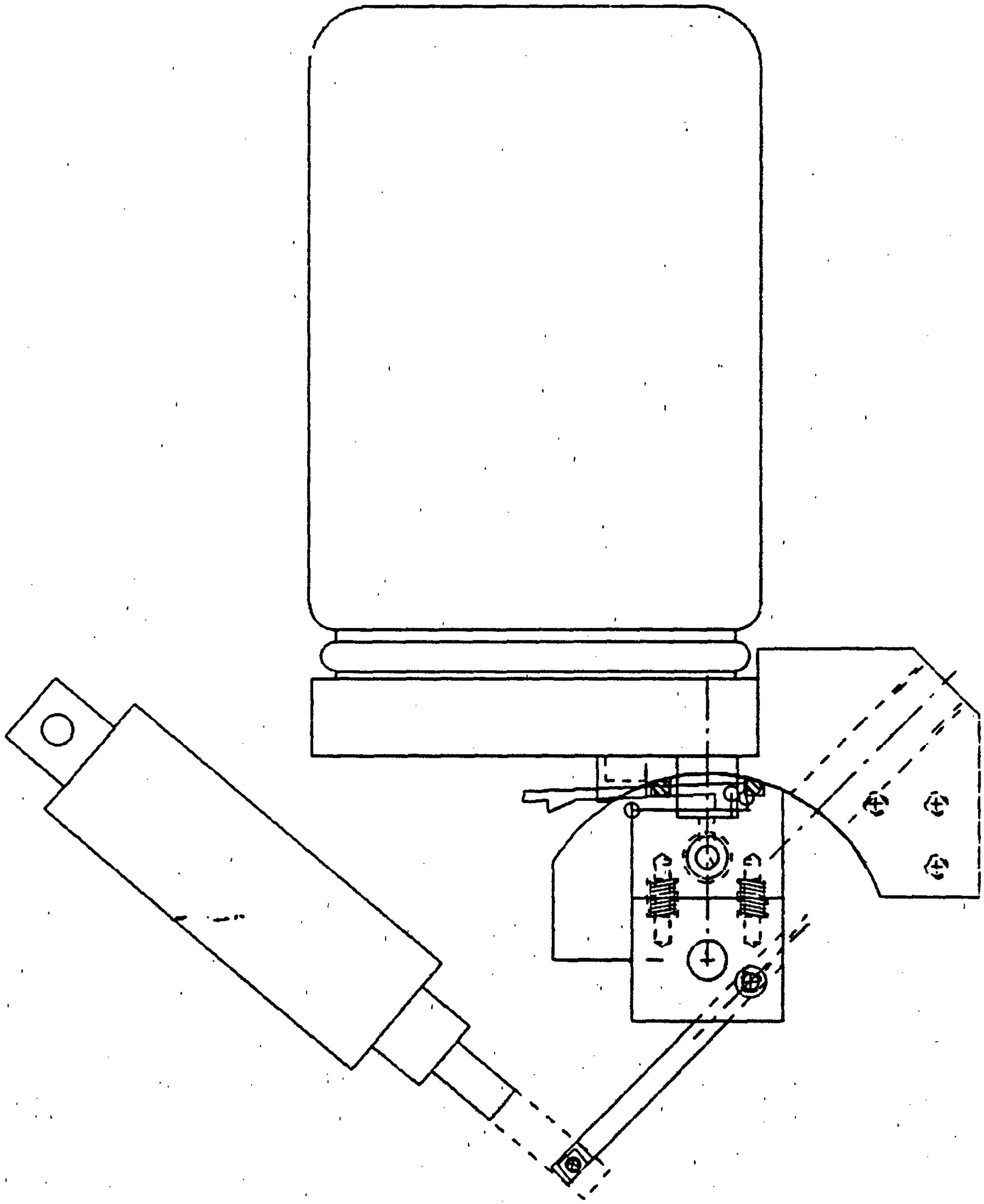


FIGURE 5. ROTARY FILL.

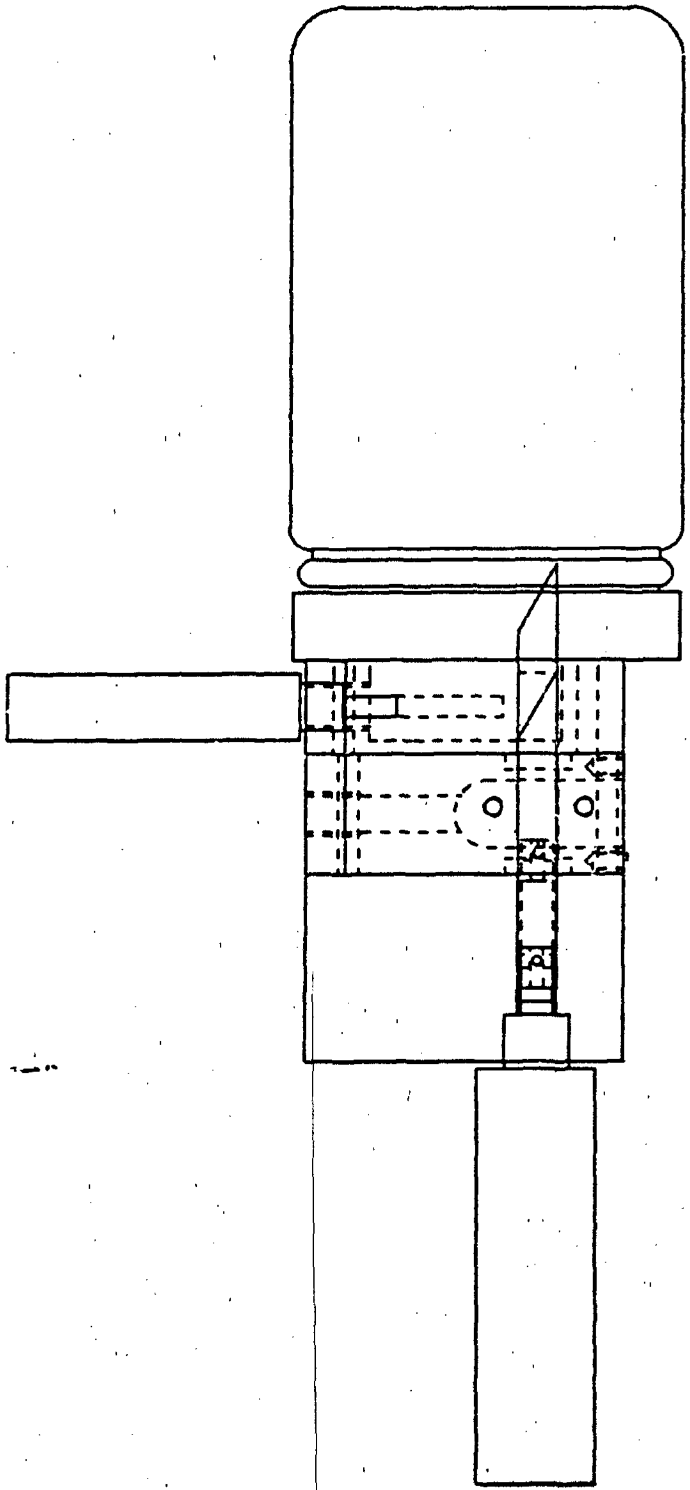


FIGURE 6. VERTICAL MEMBRANE.

employing low pressure pneumatics, the commercial devices are impractical for spray gun incorporation. Industrial metering can be based on presumed volume, as the case with the spray gun, or weight. Weight discharge requires some form of weight scale to function properly.

Based on the developed design criteria, the evaluation of the current gun meter, and the pediculicide flow characteristic testing, four conceptual meter designs were developed using CAD. Move and rotation commands were employed to verify the kinematics of various components (i.e. cylinder stroke, agitation linkages, port alignment, etc.). The four meter designs (see again figures 3,4,5 & 6) are referred to as shuttle valve, sliding membrane, rotary fill and vertical membrane respectively.

Prototypes were constructed of transparent plastic to assist assessment and/or troubleshooting of the four stage sequence of dust dispersal: (1) Volumetric hopper fill assisted by live bottom agitation, (2) actuation or relocation of the metered amount to the dispersal conduit, (3) dispersal or fluidizing of the powder down the nozzle, and (4) return by which the process is repeated. The prototypes incorporated commercial components, namely, pneumatic mini cylinders and four way toggle poppet valve. Each toggle corresponded to a different portion of the four stage sequence. During evaluation each toggle could be operated and repeated on demand, without activating the remaining sequence stages.

The shuttle valve design (figure 3) is similar to most fluid power valves. A spool, sealed against the inner diameter of a cylinder shuttles over ports allowing flow direction to change. This and each subsequent design is complicated by the necessity of providing consistent agitation. Agitation aerates the powder, hopefully achieving consistent density required for volumetric metering. The shuttle valve design incorporated an inline pneumatic actuator, which in turn drove a mechanical gear assembly providing rotary agitation in the reservoir.

The shuttle valve design jammed frequently during operation. Jamming could be attributed to O-ring drag and mechanical drive (agitation) inefficiency. In addition, consistent fill down the long slender hopper orifice was not achieved, even with good agitation.

The sliding membrane design (figure 4) incorporates two pneumatic actuators--one for actuation and a second smaller unit for agitation. The agitation actuator or cylinder would asymmetrically plow the powder into the horizontal hopper slide. An in line actuator would then place the filled hopper slide into the dispensing air path. This design did not jam or leak. However, excessive drag required the prototype to be operated at elevated system pressures (approximately 60 psig).

The rotary fill design (see figure 5) incorporated many of the same techniques used in commercial packaging of talc and powders (Yeaple 1984). Mechanical agitation is induced by the actuation cylinder extension and a small vacuum is generated on the hopper to assist powder fill. The tangent actuation cylinder is retracted, rotating a partial drum into the dispensing air path. The unit did not jam or leak. The design required numerous parts and complex, three-dimensional linkages to obtain adequate mechanical agitation.

The vertical membrane is a variation on the sliding membrane design (figure 6). Unlike the sliding membrane design, the hopper side is oriented vertically. An agitation cylinder, normal to slide travel, plows the powder into the hopper chamber. A retracting actuation cylinder then lowers the hopper into the dispensing air path. Agitation is assisted by the chamfered slide which rises into the powder for refilling. In addition, the plow possesses two rake like appendages, which stir the powder with each fill. Testing indicated the vertical slide to be the most reliable and least complex of the designs. The empty vetrical membrane meter prototype, fabricated primarily from acrylic, weighs approximately 1200 grams including all tube, toggle valves and fittings. It should be noted, however, the toggle valves are fabricated from dense brass and would not be incorporated in a production unit.

Test Method

Figure 7 depicts the test connections for the meter testing. Supply air regulation was set at a static gauge pressure of 30 psig. At supply pressure (without the gun attached) the flow regulator was restricted to 4 scfm. Briefly, the initial test procedure consisted of the following. Each prototype meter was installed on the regulating manifold. The meters were individually sequenced and dispensed via the toggle valves into an exhaust system. Visual inspection of the size and duration of the aerosol cloud was performed.

The meter designs were then tested using a polypropylene bag filter. The filter had a 3" opening which was clamped and sealed to the blower exhaust. To reduce pressure head, the filter bag flared to a 6" diameter for a length of 18". The filter had a 99% efficiency for 1 micron particle sizes. Using a precision triple beam balance, the filter was weighed before and after the meter actuation. The difference in gross weight verified the metered amount. Testing was commenced with a reservoir full of Pyrax ABB carrier dust. Each dispense duration into the bag filter was approximately 2 seconds. The prototypes were regularly inspected (every 17 actuations) for powder leakage or accumulation.

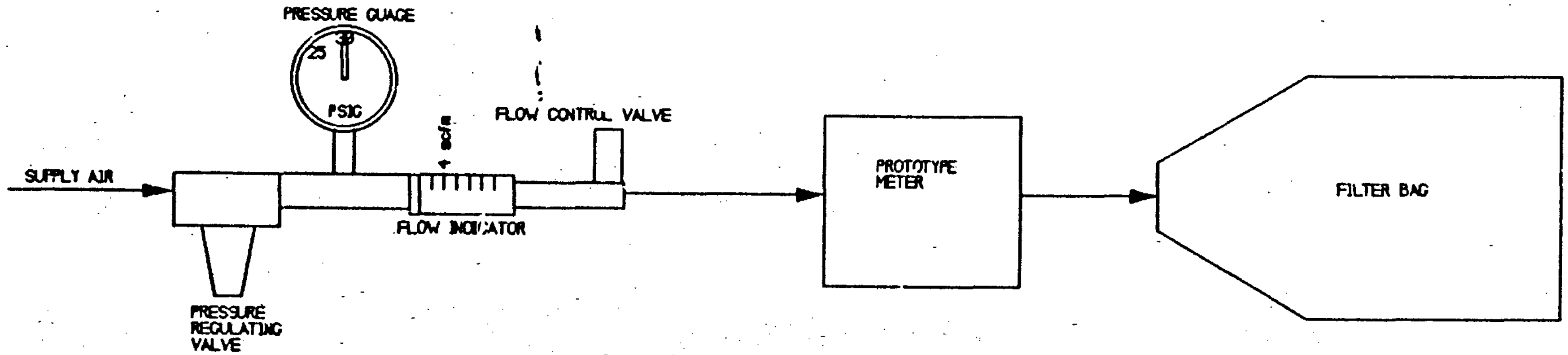


FIGURE 7. TEST CONNECTIONS.

Test Results

The shuttle valve design was eliminated due to excessive jamming. The rotary fill and sliding membrane designs exhibited no jamming and little leakage. The designs had exhibited the ability to repeatedly meter the dust when the powder was poured onto the reservoir bottom with no reservoir jar in place. With a near full capacity in the reservoir, consolidating pressures caused arching over the local agitation after several cycles. The arching was quickly collapsed with a slight manual tap or shake. As indicated by the flow property testing, accurate volumetric metering will be directly attributable to the consistency of bulk density. Therefore, we expanded the agitation components to provide complete reservoir agitation and retested.

The vertical membrane design exhibited no leakage, no jamming, and the most reliable consistent metering. Test results for the vertical membrane design are available in Table 1 and Figure 8. The prototype was actuated 153 times which translates to 9 human subjects. The data was collected at variable pressures (25-30 psig). The prototype was also pitched backward approximately 45° and rolled to either side approximately 45° with no appreciable variation from previous data. The data in figure 8 was plotted to show the amount of each metered dose and the accumulated effect of 17 actuations. The average dosage achieved was 1.4 ±0.4. The meter prototype hopper size was based on a powder density of 33.1 lbs/ft^3. This density corresponds to the minimum compaction density of the pediculicide as measured in the flow characterization testing. Variation in the dosage is attributable to measurement error and variation in dust compaction (density) due to plow agitation.

VI. Gun Integration

The conceptual prototypes concentrated on the metering device, possessing no automatic sequencing. In other words, the four sequence stages were achieved by independent toggle valves for conceptual prototype demonstration and testing. The actual dispersal sequence requires a single trigger valve; which in turn will trigger the remaining valves automatically. A fully automated approach intends to reduce operator fatigue and boost overall reliability under the myriad of potential operating conditions.

Two advanced prototypes of the vertical membrane design were machined from aluminum stock. Commercial valves and fittings were purchased and mounted external to the gun (see figure 9, valves and fittings not shown). The total weight of the advanced prototype gun including all external valves, tubes, fittings and empty resevoir was 1700 grams. The performance of the flexible dispersal nozzle demonstrated acceptable performance from the previous design and was retained. Alternative nozzles, such as coolant hoses, were

TABLE 1. VERTICAL MEMBRANE TEST

CYCL	NET WGT.	CUM.	CYCL	NET WGT.	CUM.	CYCL	NET WGT.	CUM.
1	2.00	2.0	52	1.60	1.6	103	2.00	2.0
2	1.00	3.0	53	1.50	3.1	104	1.00	3.0
3	1.00	4.0	54	1.60	4.7	105	1.30	4.3
4	1.00	5.0	55	1.30	6.0	106	1.50	5.8
5	1.00	6.0	56	1.30	7.3	107	1.10	6.9
6	0.50	6.5	57	1.80	9.1	108	1.80	8.7
7	1.50	8.0	58	1.50	10.6	109	1.40	10.1
8	0.80	8.8	59	1.40	12.0	110	1.50	11.6
9	1.20	10.0	60	1.30	13.3	111	1.50	13.1
10	1.00	11.0	61	1.50	14.8	112	1.60	14.7
11	0.30	11.3	62	1.50	16.3	113	1.40	16.1
12	1.30	12.6	63	1.70	18.0	114	1.90	18.0
13	1.20	13.8	64	1.80	19.8	115	1.60	19.6
14	1.10	14.9	65	1.50	21.3	116	1.70	21.3
15	1.10	16.0	66	1.70	23.0	117	1.20	22.5
16	1.50	17.5	67	1.40	24.4	118	1.40	23.9
17	1.00	18.5	68	1.20	25.6	119	1.50	25.4
18	1.50	1.5	69	1.50	1.5	120	1.40	1.4
19	1.90	3.4	70	1.50	3.0	121	1.50	2.9
20	1.30	4.7	71	2.40	5.4	122	1.40	4.3
21	0.40	5.1	72	2.10	7.5	123	1.40	5.7
22	1.80	6.9	73	1.40	8.9	124	0.60	6.3
23	0.90	7.8	74	1.30	10.2	125	1.60	7.9
24	1.10	8.9	75	1.70	11.9	126	1.80	9.7
25	1.10	10.0	76	1.60	13.5	127	1.40	11.1
26	1.20	11.2	77	1.70	15.2	128	1.20	12.3
27	1.60	12.8	78	1.70	16.9	129	1.20	13.5
28	1.50	14.3	79	1.40	18.3	130	1.40	14.9
29	1.30	15.6	80	1.50	19.8	131	1.20	16.1
30	1.30	16.9	81	1.90	21.7	132	1.00	17.1
31	1.30	18.2	82	1.70	23.4	133	1.60	18.7
32	0.90	19.1	83	1.20	24.6	134	1.40	20.1
33	1.50	20.6	84	1.50	26.1	135	1.40	21.5
34	1.40	22.0	85	1.30	27.4	136	1.00	22.5
35	1.00	1.0	86	0.50	0.5	137	1.50	1.5
36	1.40	2.4	87	2.00	2.5	138	1.60	3.1
37	1.10	3.5	88	1.10	3.6	139	1.40	4.5
38	1.90	5.4	89	1.90	5.5	140	1.30	5.8
39	1.30	6.7	90	1.20	6.7	141	0.90	6.7
40	1.00	7.7	91	1.50	8.2	142	0.90	7.6
41	1.10	8.8	92	1.10	9.3	143	1.00	8.6
42	1.00	9.8	93	1.20	10.5	144	1.70	10.3
43	1.60	11.4	94	1.50	12.0	145	2.00	12.3
44	0.70	12.1	95	1.40	13.4	146	2.00	14.3
45	1.70	13.8	96	1.40	14.8	147	1.50	15.8
46	0.90	14.7	97	1.40	16.2	148	1.20	17.0
47	1.00	15.7	98	1.30	17.5	149	0.90	17.9
48	0.70	16.4	99	1.70	19.2	150	2.00	19.9
49	1.50	17.9	100	1.60	20.8	151	1.40	21.3
50	2.70	20.6	101	1.70	22.5	152	1.40	22.7
51	0.90	21.5	102	1.60	24.1	153	1.90	24.6

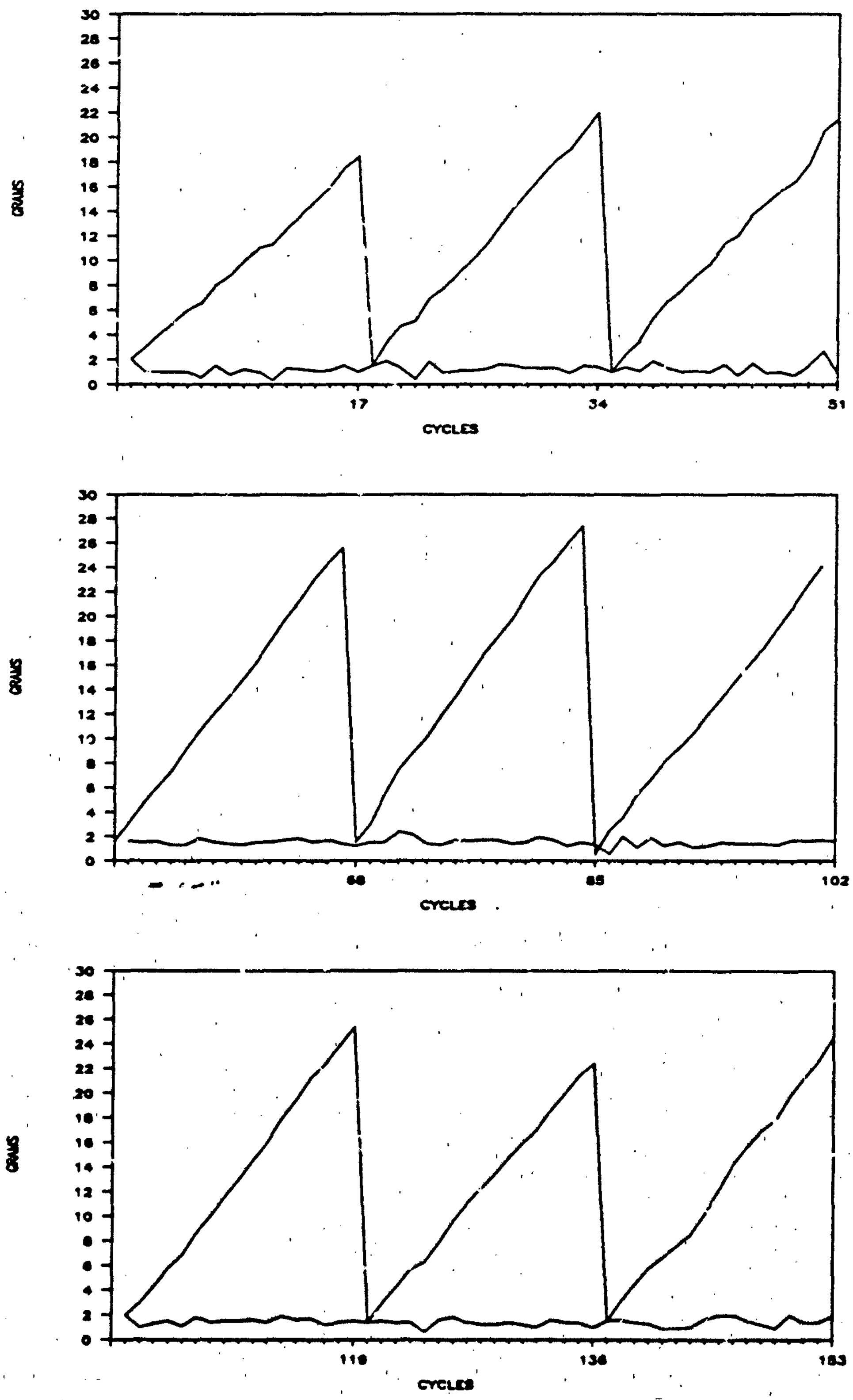
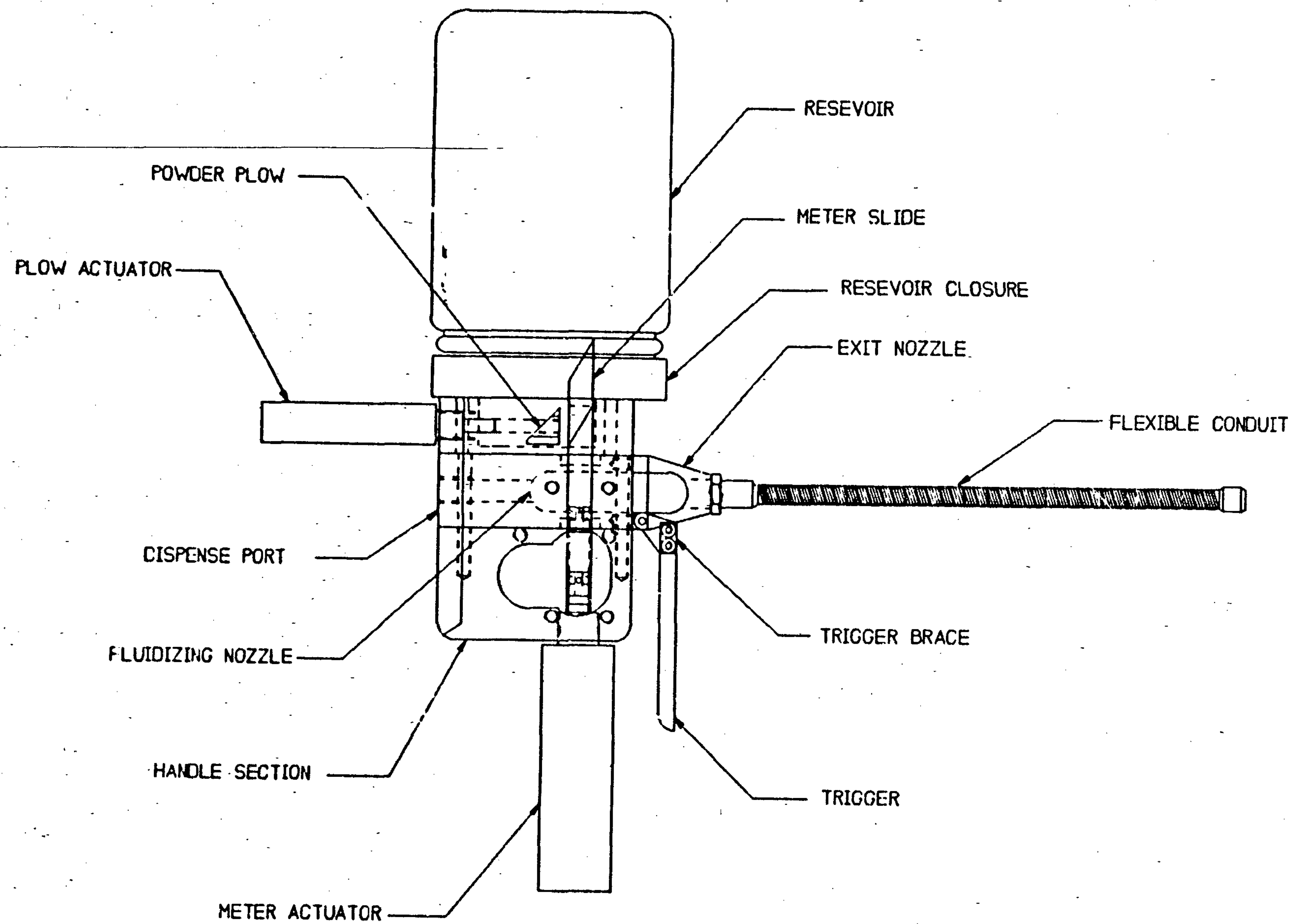


FIGURE 8. DATA PLOTTED TO SHOW THE AMOUNT OF EACH METERED DOSE AND THE ACCUMULATED EFFECT OF 17 ACTUATIONS.



VERTICAL MEMBRANE ADVANCED PROTOTYPE
(VALVES, TUBES AND FITTINGS NOT SHOWN)

FIGURE 9

evaluated and found less suitable. In some case the coolant hose samples performed well, but produced an annoying whistle at the specified pressures and flow. Several reservoir jars and closures were also evaluated. The plastic jar of the current system possesses the best combination of impact resistance, translucence and capacity (500 cc).

The advanced prototype was tested with the exact procedure of the conceptual meter prototypes; however, the advanced prototype was tested for fewer cycles and with a single trigger valve, as opposed to multiple toggle valves. Figure 10 is a representative graph of actuation dosage and accumulated dosage.

The average dosage was 2.7 ±0.4 grams of dust. The hopper size of the advanced prototype was increased from 3.4 cc to 4.1 cc as a result of low average dosages (approximately 80% of the desired 1.8 grams) from the conceptual meter testing. Subsequent to meter sizing, the speed at which the agitation or plow cylinder actuated was reduced using a bleed orifice and choker. Prior to the speed reduction the plow actuated at very rapid speed, effectively throwing powder aside. The reduced speed provides more uniform fill to the entire hopper volume. Consequently, volumetric fill slightly compacts the powder altering the average powder density; the average dosage rose substantially to 2.7 grams. The production hopper volume based on compacted pediculicide density should be specified at 2.8 cc for average dosages of 1.8 grams.

The advanced prototype possesses the functional performance features of a field delousing system. Appendix C and D include the advanced prototype Level II drawings and assembly/disassembly instructions. From evaluation of the advanced prototype increased reliability in uniform metering and improved user interface and human factors can be assessed toward a production unit configuration.

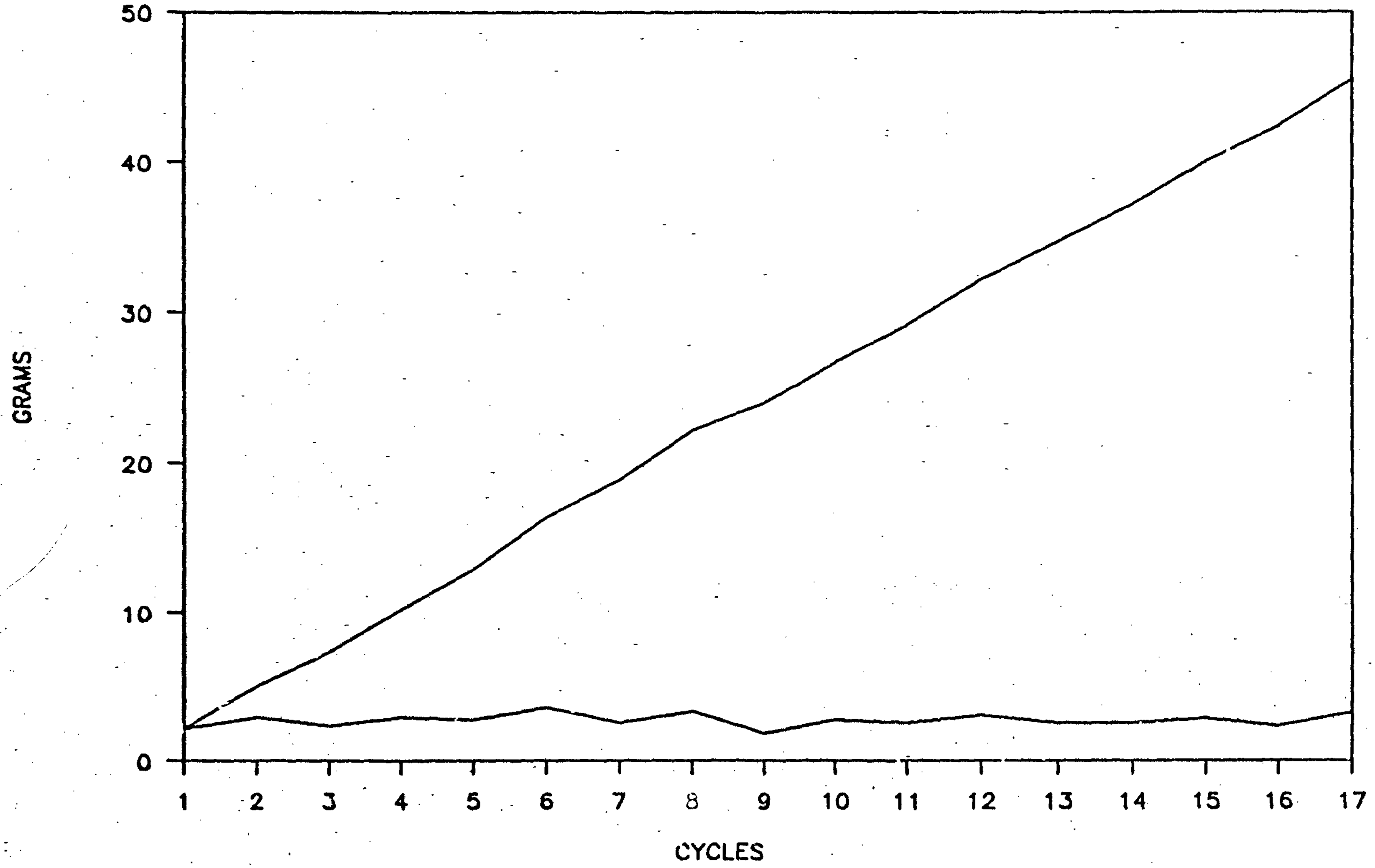


FIGURE 10. REPRESENTATIVE GRAPH OF ACTUATION DOSAGE AND ACCUMULATED DOSAGE.

VII. Conclusions and Recommendations

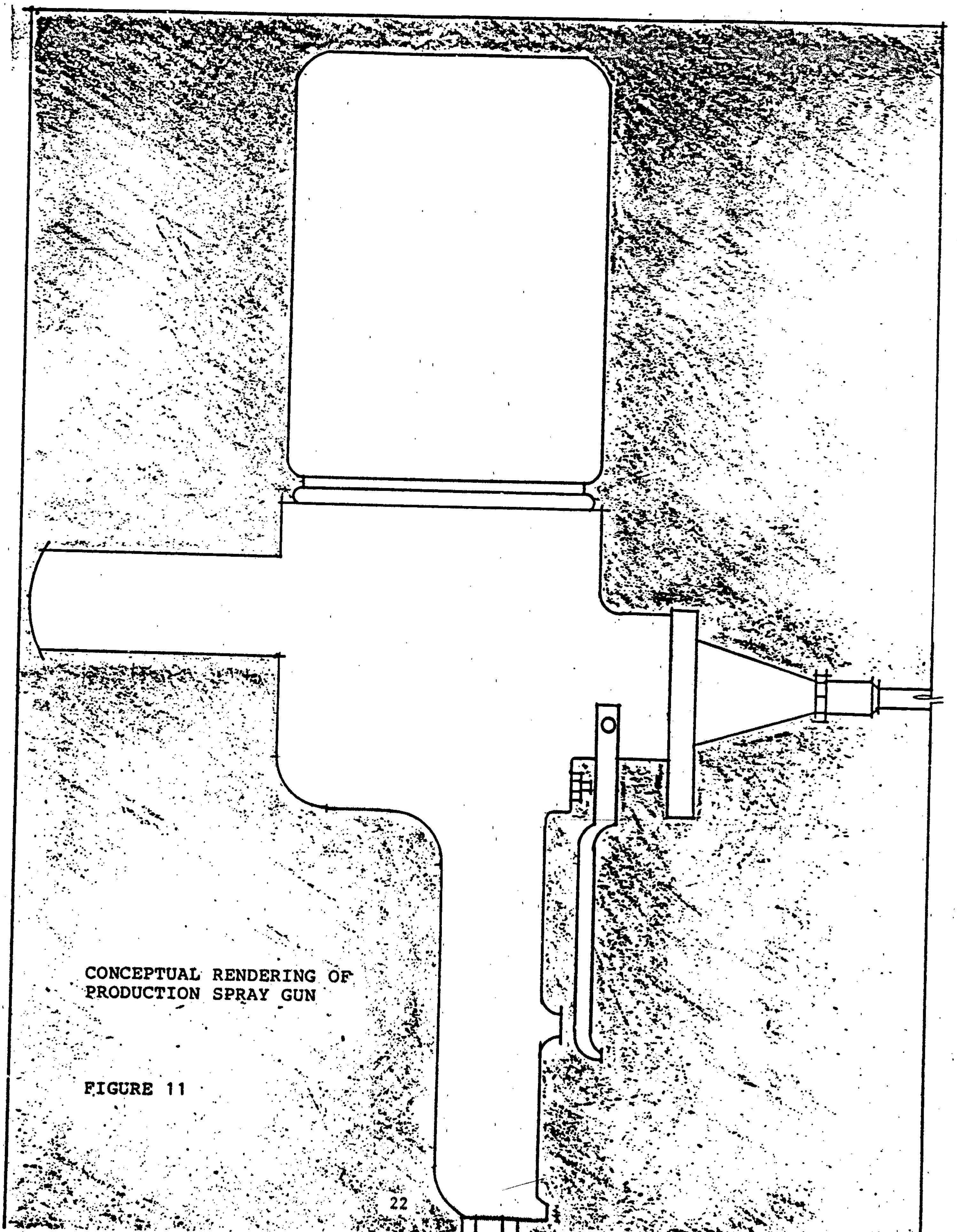
As mentioned previously, the objectives of the research were: (a) uniform and regulated pediculicide dust dispersal, (b) elimination of jamming, (c) prevention of leakage during operation, and (d) reduction of operator fatigue. The advanced prototype unit consistently performed average metering dosages of 2.7 ±.4 grams. The excessive dosage is directly attributable to increased hopper size, enlarged from assumed pediculicide density as a result of meter testing. The correct hopper size specification is 2.8 cc for a production hopper volume.

At no time during testing of the meter or advanced prototype did the units leak, due in full to the Buna-N O-ring specification. Both prototype units possessed O-ring drag on the meter slide. This resulted from prototype O-ring grooves which were cut undersized (not to print). The O-ring was over-compressed for the application; the O-ring grooves were subsequently enlarged. Following the correction of the parts no jamming was encountered, at pressures as low as 25 psig and after repeated actuation.

Incorporated into the prototype testing, the gun was repeatedly actuated into the filter bag at varying pitches, rolls, and elevations in order to more accurately replicate the actual delousing operation. We estimate 17 applications, single subject delousing, can be performed well within 1 minute (60 seconds).

Operator fatigue was substantially diminished with respect to the gun trigger. The current gun requires greater than ten pounds of compression force for actuation. This force does not include jamming friction due to powder build-up on the drum. The advanced prototype requires less than 1 lbs at the trigger. The weight of the advanced prototype is excessive, 1700 grams; almost twice that of the present gun. The vast majority of the prototype's weight is in the use of machined aluminum material, external brass valves, fittings and cylinders. We believe a production gun's weight could be reduced by a factor of 2, by using alternative material (i.e. delron) and incorporating cartridge valves and air passages internal to the gun.

Based on the research and the continued need for mass human delousing capability, we recommend the development of a production spray gun, incorporating the changes mentioned above. Figure 10 is a conceptual rendering of a production gun configuration--repackaging of cylinders, valves and air passages, in a lighter material with rugged handle. The production gun would relocate quick disconnect valve fitting to a less intrusive location (i.e. on the butt of the handle).



CONCEPTUAL RENDERING OF
PRODUCTION SPRAY GUN

FIGURE 11

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APPENDIX A: Historical Background

APPENDIX A: Historical Background

For human delousing, the U.S. Army employs 1% malathion dust applied to 17 sites on the body. Total dosage per subject has been specified at 30 grams. If distributed evenly about the 17 sites, the single shot dosage equates to 1.765 grams, or approximately 1.8 grams per site. Effective dust application will include skin, hair and surrounding clothing fibers, which adult lice, nymphs and eggs (nits) inhabit.

Malathion dust is an organophosphate cholinesterase inhibitor. Malathion is considered one of the least toxic organophosphorus insecticides. Ten percent (10%) malathion dust produces little or no blood cholinesterase after daily application to human skin (Med Lett Drugs Ther, 1989). The recommended dosage of 1% malathion dust is 30 grams evenly distributed over the 17 discharge sites or 1.8 grams per site (Barnes et al,1962). In commercial formulation, a malathion prescription performed superior to nonprescription pyrethrin with piperonyl butoxide and prescription lindane (Meinking et al, 1986). The chief complaint of malathion is the unpleasant odor.

For the pediculicide application to be effective, a dust dispersal nozzle must be placed in close proximity to the site during application. Adult body lice are quite mobile with the ability to travel as far as nine inches per minute at room temperature. Females may lay as many as 10 eggs a day in a one month lifetime. The correct dosage should be well distributed on the skin, hair and surrounding clothing to eradicate lice gestation.

During World War II and the Korean conflict, subject dusting was accomplished using manual spray guns with linear or rotary type actuation. Immediately following WWII, a large ($0.5m^3$) mass human delousing system was developed. The system had a 600 subject per hour capacity, weighing 121.5 kg. The actuation continuously discharged pediculicide as long as the valve or trigger was depressed. The dosage of pediculicide was controlled by the approximate duration of the discharge. The method was inaccurate; coupled with a philosophy which erred toward over application. The WWII era equipment is now obsolete, replaced by a system weighing half as much and occupying half the volume.

During World War II and the Korean conflict, the U.S. Army performed mass delousing on hundreds of thousands of refugees and POWs. A dust containing 10 percent DDT insecticide in a neutral carrier was blown under the clothing. DDT was later banned due to the tendency for accumulation in ecosystems and subsequent toxic effect on birds and many other vertebrates.

More recently lindane, an organochlorine insecticide dust formulation, was the preferred military pediculicide. Lindane pediculicide was applied to 17 sites per person (maximum 68 grams/person) in amounts of approximately 2 to 4 grams/site. Body lice have demonstrated resistance and some immunity to lindane; the insecticide may also pose adverse effects on human health.

Like malathion, a permethrin product was more effective than pyrethrin or lindane at eradicating head lice (DiNapoli et al, 1988; Carson et al, 1988). Permethrin-treated military uniform fabric recorded effective body lice knockdowns in field and laboratory results (Sholdt et al, 1989). Permethrin as a dust formulated pediculicide has been successfully applied in Egypt (Nassif, 1980). Although Malathion remains the preferred dust pediculicide, delousing equipment could be readily adapted (with negligible design consequence) to multiple dust formulations and batch sizes; by means of hopper retrofit.

The bites of human body lice (Pediculus humanas,L.), their body fluids, or their feces can transmit trench fever, relapsing fever, scrub typhus and the pathogenic microbes of epidemic typhus. Large scale military conflict or natural disaster could lead to lice infestation and the rapid, epidemic spread of disease. The U.S. military could be responsible for epidemic prevention in POW or refugee camps. Development of efficient systems for mobile and wholesale application of pediculicide maximizes resources while advancing the total capability for meeting a large scale, remote demand.

Permethrin treated fabric could provide excellent protection to U.S. military personnel. Eradication among refugees and POWs remains a question. U.S. troops have not participated in a mass human delousing operation in over 30 years. Should the requirement for mass human delousing equipment remain, a rapid safe means of applying pediculicide would be valuable to the Army, domestic and international relief organizations, and the World Health Organization. Operator safety, subject safety and general public health dictate the precise metering and control of the pediculicide.

APPENDIX A: Bibliography

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APPENDIX B: Pediculicide Flow Property Test Report

FLOW PROPERTIES TEST REPORT

Cardinal Scientific

912447

Jenike & Johanson, inc.
STORAGE AND FLOW OF SOLIDS

2 Executive Park Drive-North Billerica, MA 01862-(508)-667-5136

CONTENTS

INTRODUCTION

This test report describes the flow properties of your material. These properties are expressed in terms of bin dimensions required to ensure dependable flow, maximum hopper angles for mass flow and, if tested, minimum chute angles and critical discharge rates through bin outlets. All dimensions represent limiting conditions for flow; therefore, larger outlets, steeper hoppers and chutes, and flow rates below critical are acceptable. If your material is one which will compact excessively in a large bin, the largest diameter or width and height of the cylinder to limit this compaction is also given.

In case you are unfamiliar with the use of this type of data, an Appendix follows the main body of the report. Most of the symbols used in the report are shown in the figures on pages A16 to A18. A Glossary of Terms and Symbols is provided on pages A12 to A15.

GENERAL COMMENTS

A 1/2 gallon sample of Malathion douse was received for testing which required use of our small testing equipment utilizing a one inch diameter cell. A series of abbreviated comparative tests were run at 72°F, 90°F and 110°F to see if the material's flow properties were influenced by elevated temperature. The results indicated no significant difference with temperature. A full series of tests were then run at room temperature.

The powder is very compressible ($\beta = 0.094$) and is somewhat cohesive. The minimum outlet diameter for a mass flow conical hopper is 1.3 feet for gravity conditions and increases to 3.9 ft. for consolidating conditions twice that of gravity (P-Factor = 2.00).

The wall friction angle on 304 stainless steel sheet with a 2B surface finish is 29° while for a #1 mill finish plate it ranges from 37° at high consolidating pressures (166 psf) to 43° at low consolidating pressures (11 psf).

The permeability of the bulk to air flow is quite low and because of the high compressibility of the bulk, the permeability ranges from 0.006 ft/sec. at 36 pcf to 0.0004 ft/sec. at 69 pcf.

SUMMARY OF TESTS PERFORMED

This report presents various flow property test results as indicated for the following material(s) :

BULK MATERIAL	MATERIAL ID #	DESCRIPTION	PARTICLE SIZE	MOISTURE CONTENT
1	17163	Douse Malatnion	As Rec'd	0.71%
2	17169	Douse Malathion	As Rec'd	0.71%
3	17170	Douse Malathion	As Rec'd	0.71%

BULK MATERIAL	TIME hr	TEMPERATURE deg F	SIEVE ANALYSIS	BIN DIM	BULK DENSITY	HOPPER ANGLES	CHUTE ANGLES	FLOW RATE	1 PT FF
1	0.0	72		X	X	X		X	X
	8.0	72		X					
	24.0	72				X			
2	0.0	90							X
3	0.0	110							X

BULK MATERIAL 1: Douse Malathicn

PARTICLE SIZE As Rec'd

MOISTURE CONTENT 0.71%

SECTION I. BIN DIMENSIONS FOR DEPENDABLE FLOW

STORAGE TIME AT REST 0.0 hr
TEMPERATURE 72 DEG F

PART A. BINS WITH UNLIMITED MAXIMUM SIZE

WEDGE

OPTIMUM MASS FLOW DIMENSICNS

P-FACTOR	BC (ft)	BP (ft)
1.00	1.3	0.6
1.25	1.6	0.7
1.50	1.9	0.9
2.00	3.9	1.5

FUNNEL FLOW DIMENSIONS

P-FACTOR	BF (ft)	EH= 2.5	5	9 ft
		CRITICAL RATHOLE DIAMETERS, DF (ft)		
1.00	0.8	3.7	7	13
1.25	1.1	4.4	9	16
1.50	1.8	5	11	19
2.00	***	7	14	25

*** Denotes a dimension larger than 3.8 ft

TERMS

P-FACTOR = overpressure factor
BC = recommended minimum outlet diameter, conical hopper
BP = recommended minimum outlet width, slotted or oval outlet
BF = minimum width of rectanglar outlet in a funnel flow bin
EH = effective consolidating head

For detailed explanations of terms see appendix pages A5, A6, and A7.

BULK MATERIAL 1: Douse Malathion

PARTICLE SIZE As Rec'd

MOISTURE CONTENT 0.71%

STORAGE TIME AT REST 8.0 hr
TEMPERATURE 72 DEG F

PART A. BINS WITH UNLIMITED MAXIMUM SIZE

OPTIMUM MASS FLOW DIMENSIONS

P-FACTOR	BC (ft)	BP (ft)
1.00	1.6	0.8
1.25	1.9	0.9
1.50	2.5	1.1
2.00	6.8	2.2

FUNNEL FLOW DIMENSIONS

P-FACTOR	BF (ft)	EH= 2.5	5	9 ft
		CRITICAL RATHOLE DIAMETERS, DF (ft)		
1.00	1.0	4.0	8	14
1.25	1.5	4.8	10	18
1.50	3.1	6	11	21
2.00	***	7	15	28

*** Denotes a dimension larger than 4.1 ft

TERMS

P-FACTOR = overpressure factor
BC = recommended minimum outlet diameter, conical hopper
BP = recommended minimum outlet width, slotted or oval outlet
BF = minimum width of rectanglar outlet in a funnel flow bin
EH = effective consolidating head

For detailed explanations of terms see appendix pages A5, A6, and A7.

BULK MATERIAL 1: Douse Malathion

PARTICLE SIZE As Rec'd

MOISTURE CONTENT 0.71%

SECTION II. SOLIDS DENSITY

TEMPERATURE 72 deg F

BULK DENSITY
The bulk density, GAMMA, is a function of the major consolidating pressure, SIGMA1, expressed in terms of effective head, EH:

EH (ft)	0.5	1.0	2.5	5.0	10.0	20.0	40.0	80.0
SIGMA1 (psf)	22.	47.	129.	277.	595.	1280.	2751.	5913.
GAMMA (pcf)	43.6	46.8	51.5	55.4	59.5	64.0	68.8	73.9

COMPRESSIBILITY PARAMETERS

Bulk density, GAMMA, is a function of the major consolidating pressure SIGMA1, as follows:

GAMMA is the greater of GAMMA0 $(SIGMA1/SIGMA0)^{BETA}$ and GAMMAM.

For GAMMA between 46.2 and 67.5 pcf

GAMMA0 = 41.5 pcf

SIGMA0 = 13.0 psf

BETA = 0.09433

Minimum bulk density GAMMAM = 33.1 pcf

PARTICLE DENSITY
The weight density of an individual particle of the solid is
CAPGAMMA = 161.0 pcf

BULK MATERIAL 1: Douse Malathion

PARTICLE SIZE As Rec'd

MOISTURE CONTENT 0.71%

SECTION III. MAXIMUM HOPPER ANGLES FOR MASS FLOW

WALL MATERIAL: 304 #2B Finish Stainless Steel Sheet
STORAGE TIME AT REST 0.00 hrs
TEMPERATURE 72 deg F

HOPPER ANGLES FOR VARIOUS HOPPER SPANS

DIA OF CONE (ft)	0.37	0.50	1.00	2.00	4.00	4.50
WIDTH OF OVAL (ft)	0.20	0.26	0.53	1.06	2.11	2.38
SIGMA (psf)	6.2	8.6	18.	40.	85.	97.
SIGMA1 (psf)	8.5	11.8	25.	54.	117.	133.
Wall Friction Angle						
PHI-PRIME (deg)	29.	29.	29.	29.	29.	29.
Hopper Angles						
THETA-P (deg)	21.	21.	21.	21.	21.	21.
THETA-C (deg)	11.	11.	11.	11.	11.	11.

WALL MATERIAL: 304 #2B Finish Stainless Steel Sheet
STORAGE TIME AT REST 24.0 hrs
TEMPERATURE 72 deg F

No time effect! Use results from test having storage time at rest of 0.0 hrs.

BULK MATERIAL 1: Douse Malathion

PARTICLE SIZE As Rec'd

MOISTURE CONTENT 0.71%

WALL MATERIAL: 304 #1 Mill Finish Stainless Steel
STORAGE TIME AT REST 0.00 hrs
TEMPERATURE 72 deg F

HOPPER ANGLES FOR VARIOUS HOPPER SPANS

DIA OF CONE (ft)	0.43	0.50	1.00	2.00	4.00	5.14
WIDTH OF OVAL (ft)	0.23	0.27	0.54	1.08	2.16	2.77
SIGMA (psf)	6.2	7.2	16.	34.	73.	97.
SIGMA1 (psf)	11.0	12.9	28.	59.	126.	166.
Wall Friction Angle PHI-PRIME (deg)	43.	42.	39.	38.	37.	37.
Hopper Angles THETA-P (deg)	10.*	10.*	10.*	10.	11.	11.
THETA-C (deg)	0.*	0.*	0.*	0.	1.	2.

* Flow along walls is questionable.

BULK MATERIAL 1: Douse Malathion

PARTICLE SIZE As Rec'd

MOISTURE CONTENT 0.71%

SECTION IV. CRITICAL STEADY SOLIDS FLOW RATES IN Nitrogen

TEMPERATURE 72.0 deg F

CONICAL MASS FLOW HOPPER

Flow rate expressed in units of tons/hr.

BC	EH = 2.5 ft	5.0 ft	10.0 ft	20.0 ft	40.0 ft
2.00 ft	0.93	0.67	0.53	0.44	0.38
4.00 ft	9.9	7.1	5.6	4.7	4.1
8.00 ft	52.	37.	30.	25.	22.

TRANSITION MASS FLOW HOPPER

Flow rate expressed in units of tons/hr per foot length of outlet.

BP	EH = 2.5 ft	5.0 ft	10.0 ft	20.0 ft	40.0 ft
0.75 ft	0.00	0.00	0.00	0.00	0.00
1.00 ft	0.24	0.17	0.13	0.11	0.10
2.00 ft	1.5	1.0	0.87	0.73	0.63
4.00 ft	4.0	2.9	2.3	1.9	1.7
8.00 ft	9.2	6.6	5.2	4.4	3.8

TERMS

BC = diameter of circular outlet
BP = width of slotted outlet
EH = effective consolidating head

BULK MATERIAL 1: Douse Malathion

PARTICLE SIZE As Rec'd

MOISTURE CONTENT 0.71%

SECTION V. Nitrogen PERMEABILITY TEST RESULTS

Temperature 72 deg F

K, the Nitrogen permeability factor of the solid is defined from Darcy's law in following form:

$$K = -u \text{ (GAMMA) } / \text{ (dp/dx)}$$

where:

u = superficial Nitrogen velocity through the bed of solids

dp/dx = Nitrogen pressure gradient across the bed

GAMMA = bulk density of the solid in the bed

K is a function of the bulk density of the solid

$$K = K0 \text{ (GAMMA / GAMMA0)}^{-a}$$

At room temperature, for GAMMA between 36.6 and 63.7 pcf:

K0 = 0.003159 fps

GAMMA0 = 41.5 pcf

a = 4.72

plot10936 eng

BULK MATERIAL: Douse Malathion
PARTICLE SIZE: As Rec'd
MOISTURE % WT: 0.71%

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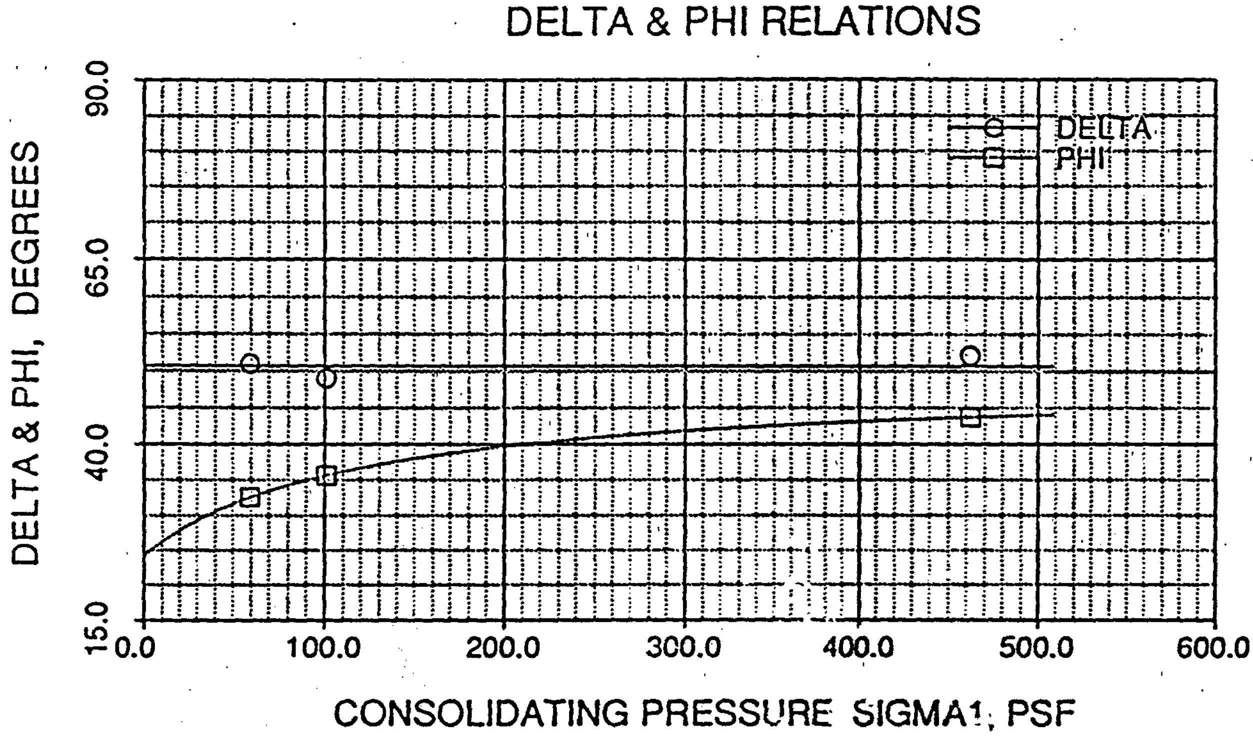

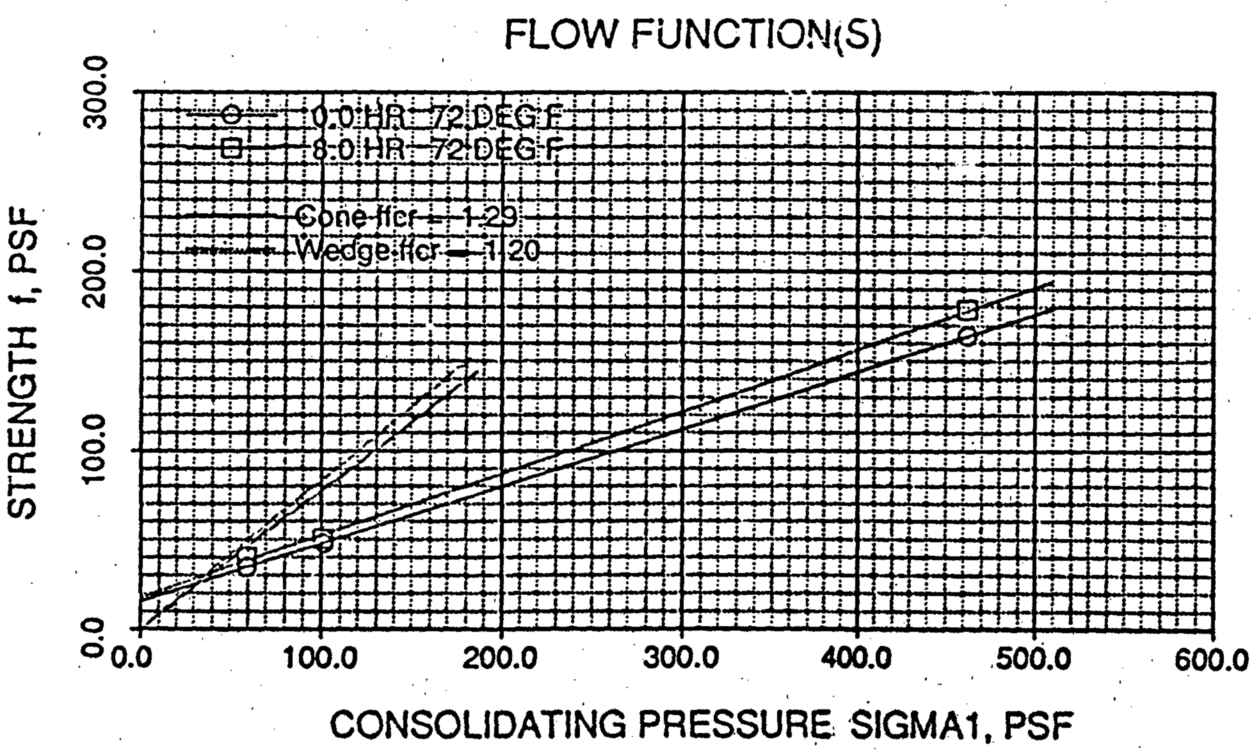

Jenike & Johanson, Inc.

plot10939 eng

BULK MATERIAL: Douse Malathion
PARTICLE SIZE: As Rec'd
MOISTURE % WT: 0.71%

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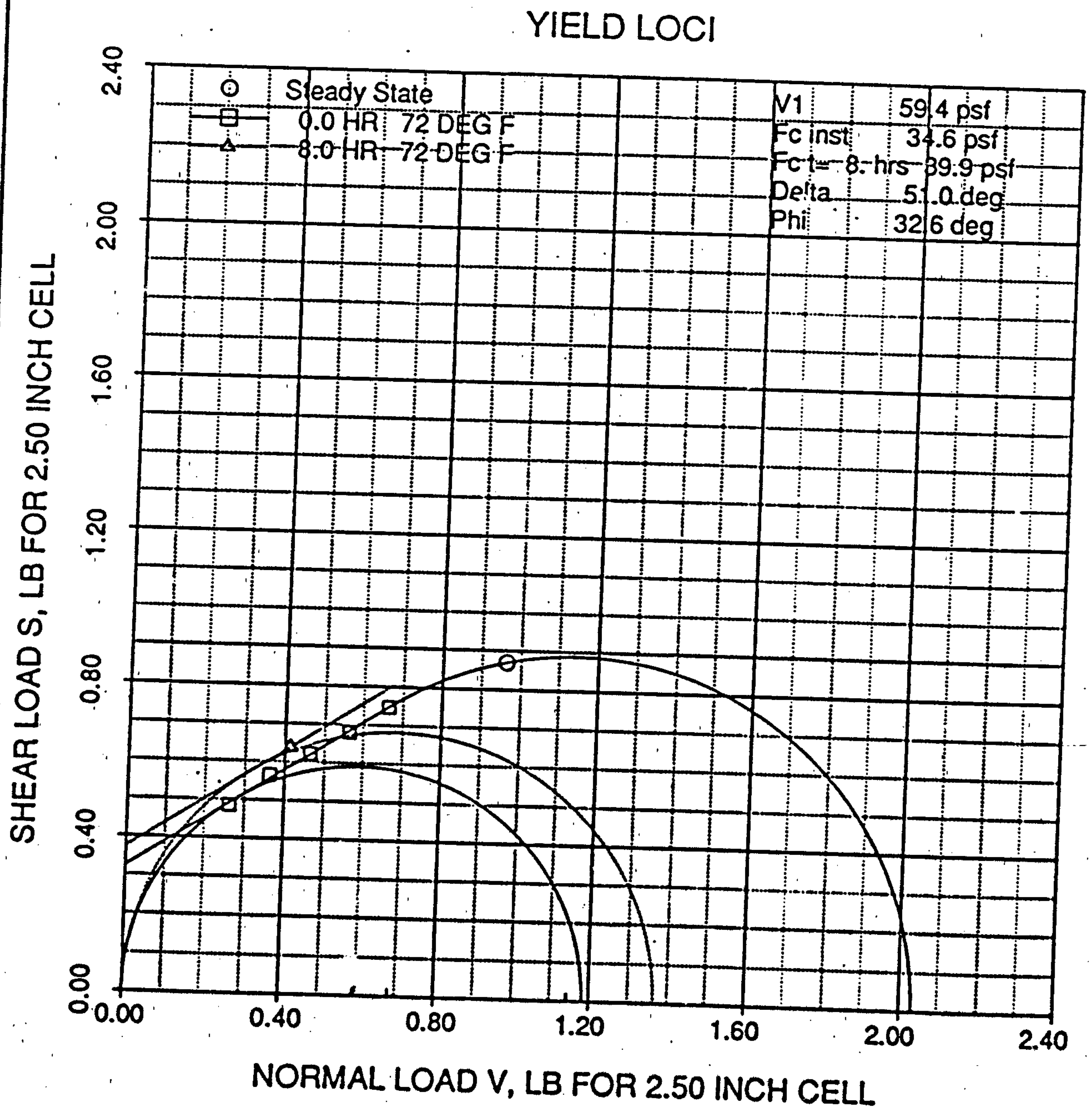

Jenike & Johanson, Inc.

BULK MATERIAL: Douse Malathion
PARTICLE SIZE: As Rec'd
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plot10938 eng

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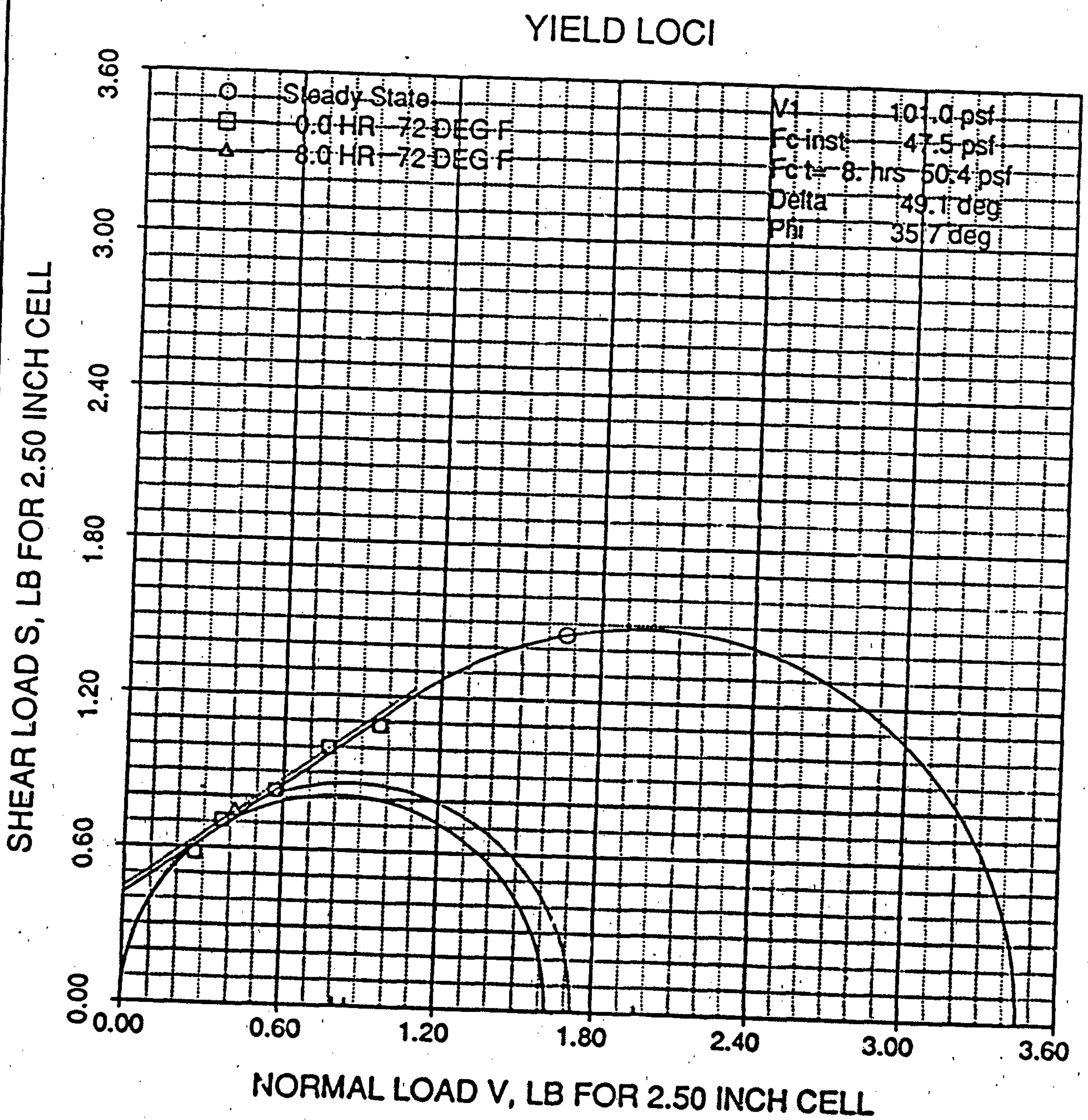

plot10937 eng

BULK MATERIAL: Douse Malathion
PARTICLE SIZE: As Rec'd
MOISTURE % WT: 0.71%

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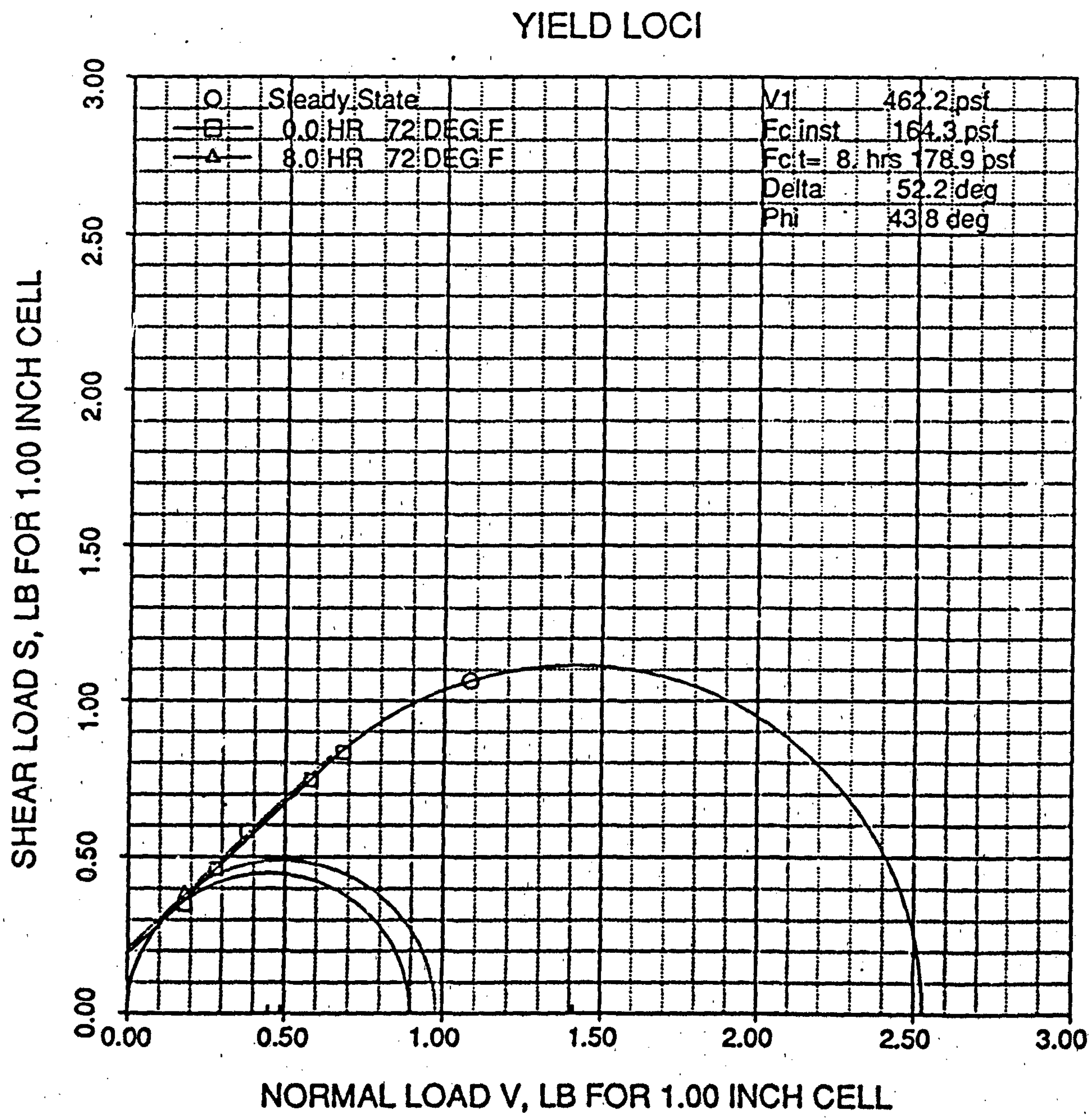
RUN: 91/05/09

JOB#: 912447
ID#: 17163



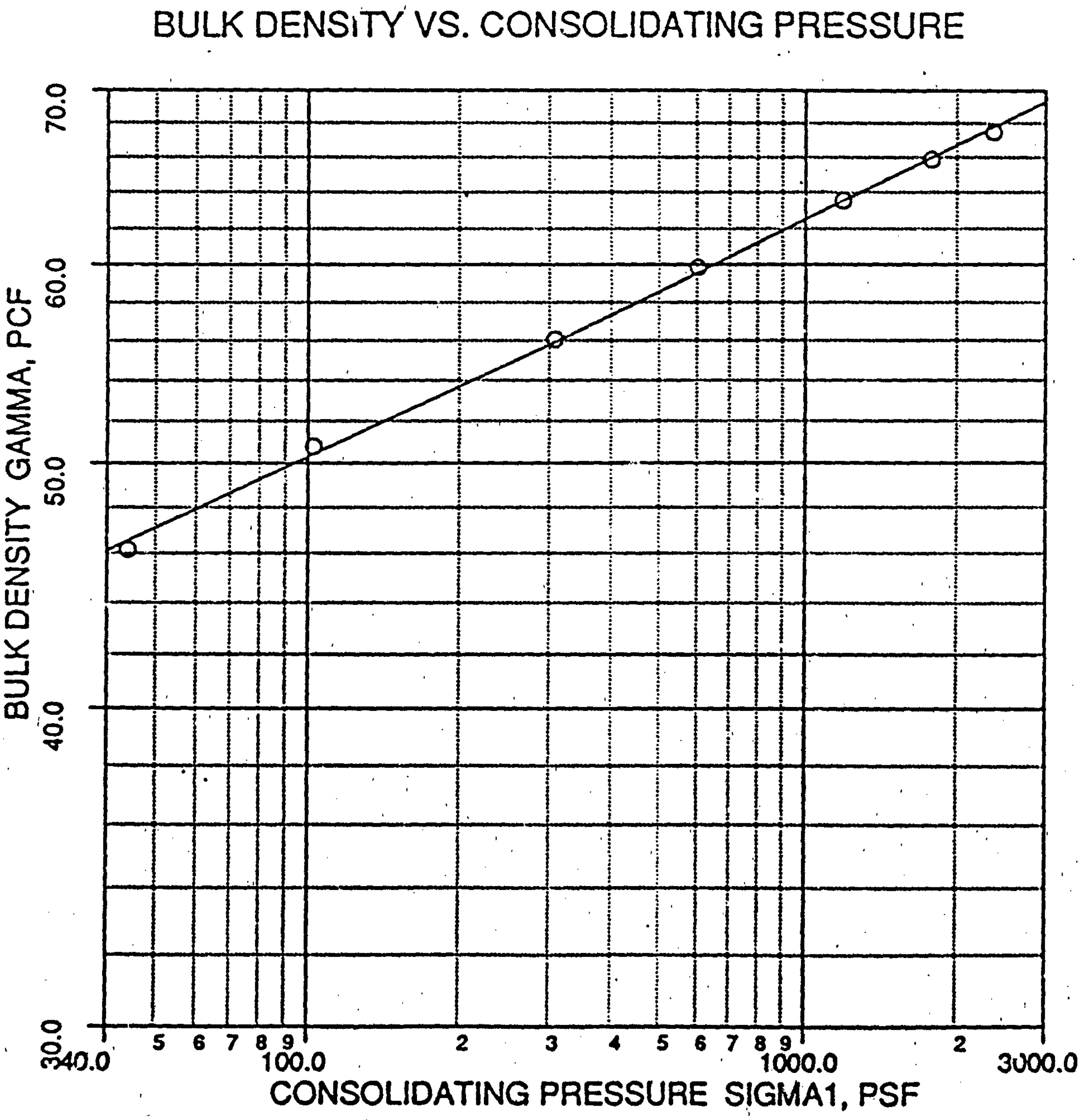
Jenike & Johanson, Inc.

plot10898 lab

BULK MATERIAL: Douse Malathion
PARTICLE SIZE: As Rec'd
MOISTURE % WT: 0.71%
TEMPERATURE: 72 DEG F

CREATE: 91/04/30
RUN: 91/05/06

JOB#: 912447
ID#: 17163



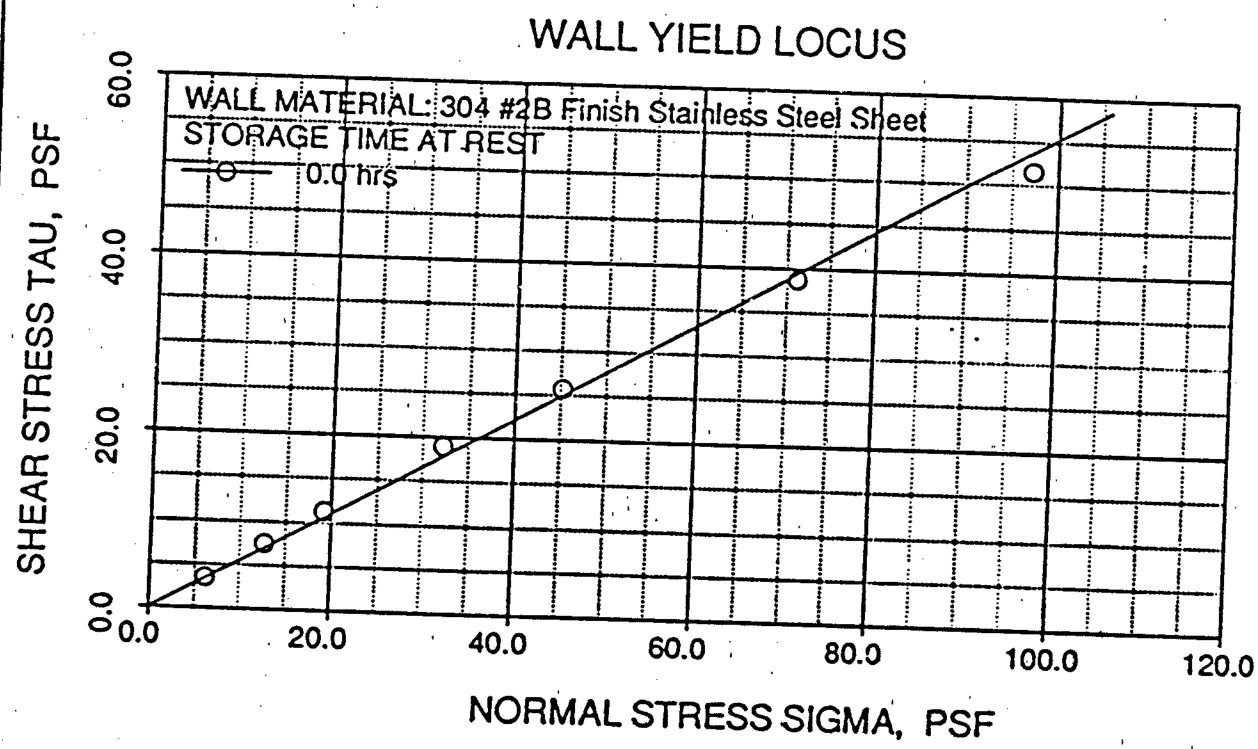
Jenike & Johanson, Inc.

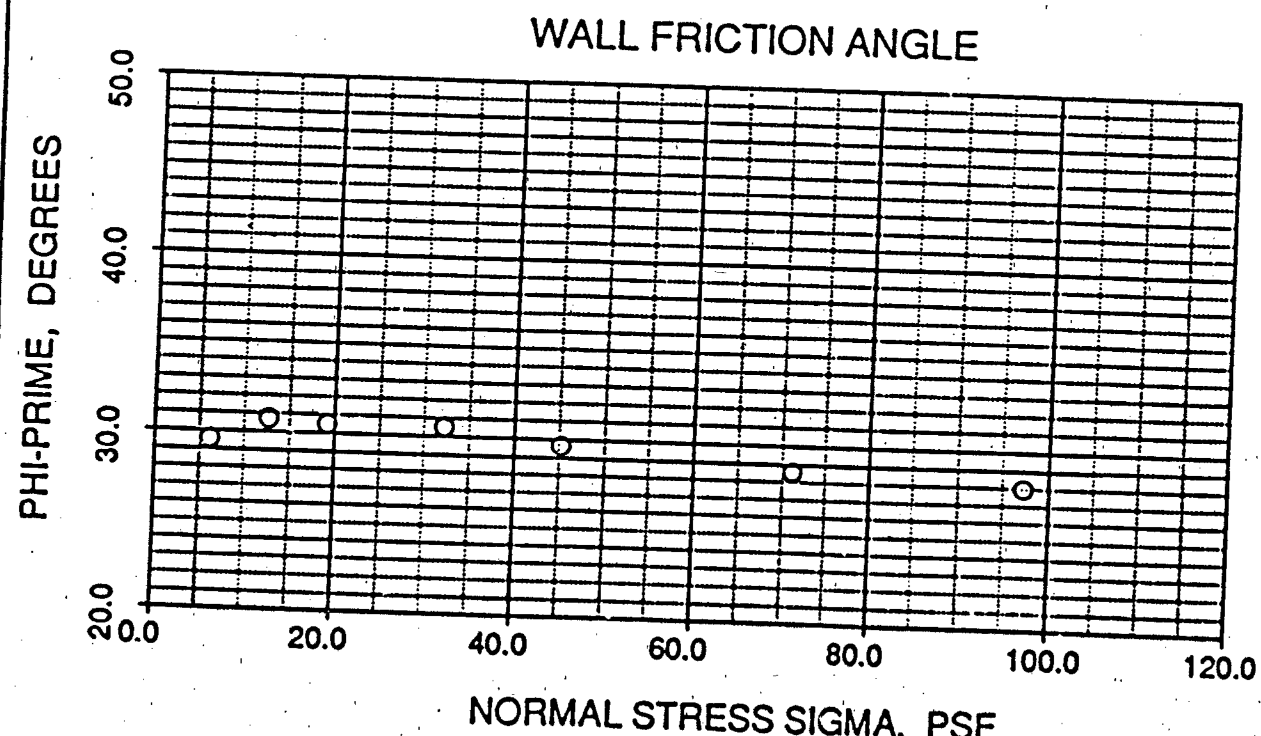
plot11000 lab

BULK MATERIAL: Douse Malathion
PARTICLE SIZE: As Rec'd
MOISTURE % WT: 0.71%
TEMPERATURE 72 deg F

CREATE: 91/04/30
RUN: 91/05/11

JOB#: 912447
ID#: 17163





Jenike & Johanson, Inc.

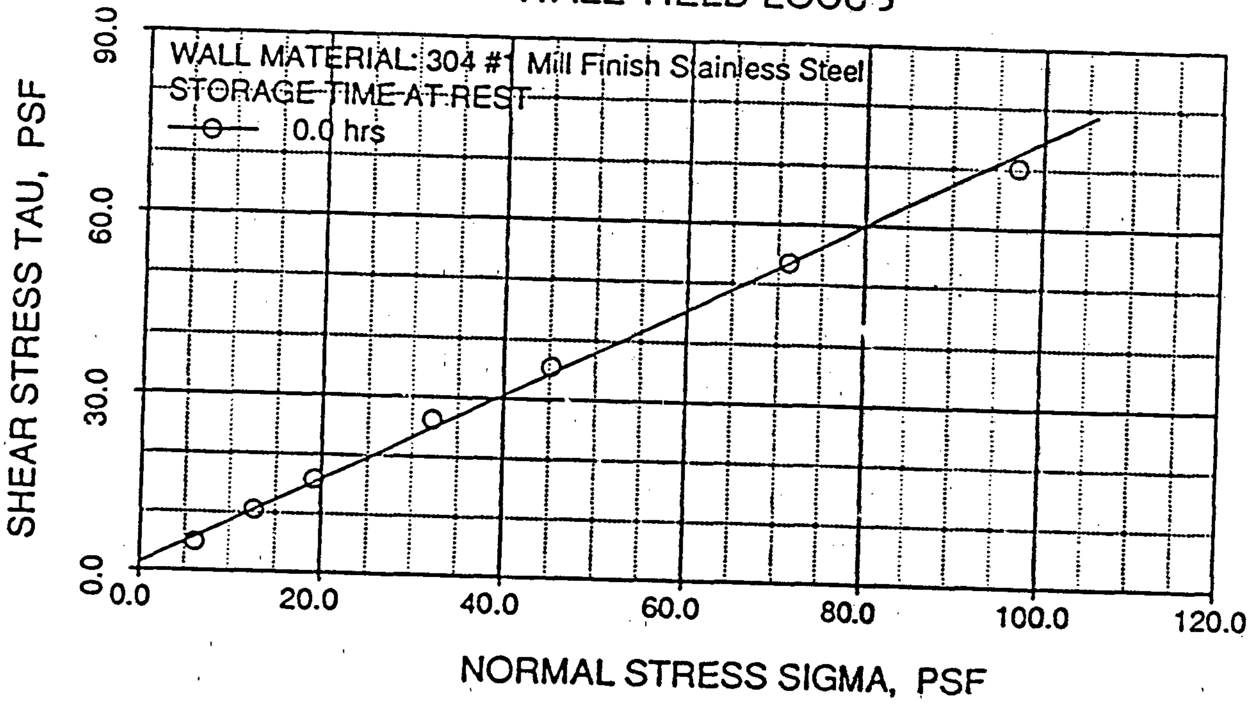
plot11001 lab

BULK MATERIAL: Douse Malathion
PARTICLE SIZE: As Rec'd
MOISTURE % WT: 0.71%
TEMPERATURE 72 deg F

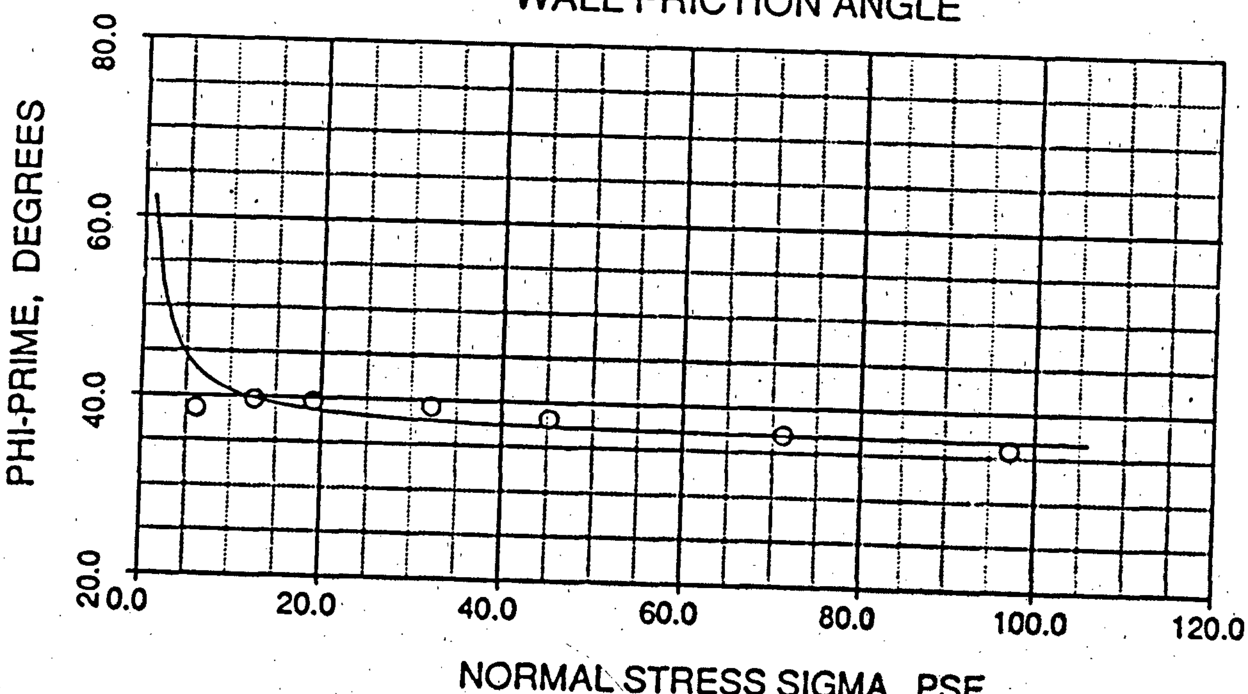
CREATE: 91/04/30
RUN: 91/05/11

JOB#: 912447
ID#: 17163

WALL YIELD LOCUS



WALL FRICTION ANGLE



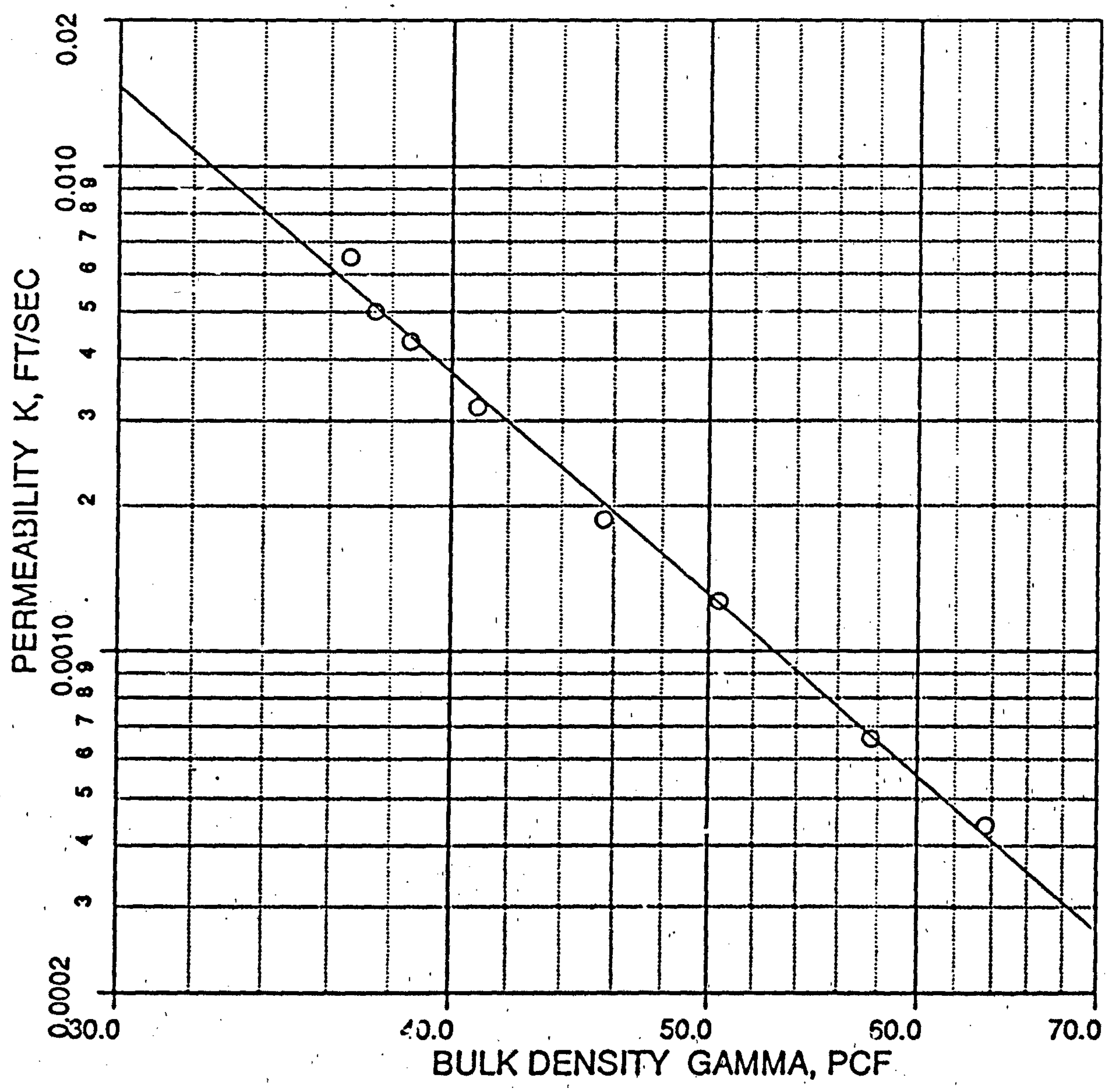
plot11002 lab

BULK MATERIAL: Douse Malathion
PARTICLE SIZE: As Rec'd
MOISTURE % WT: 0.71%
Temperature 72 deg

CREATE: 91/04/30
RUN: 91/05/11

JOB#: 912447
ID#: 17163

PERMEABILITY VS. BULK DENSITY



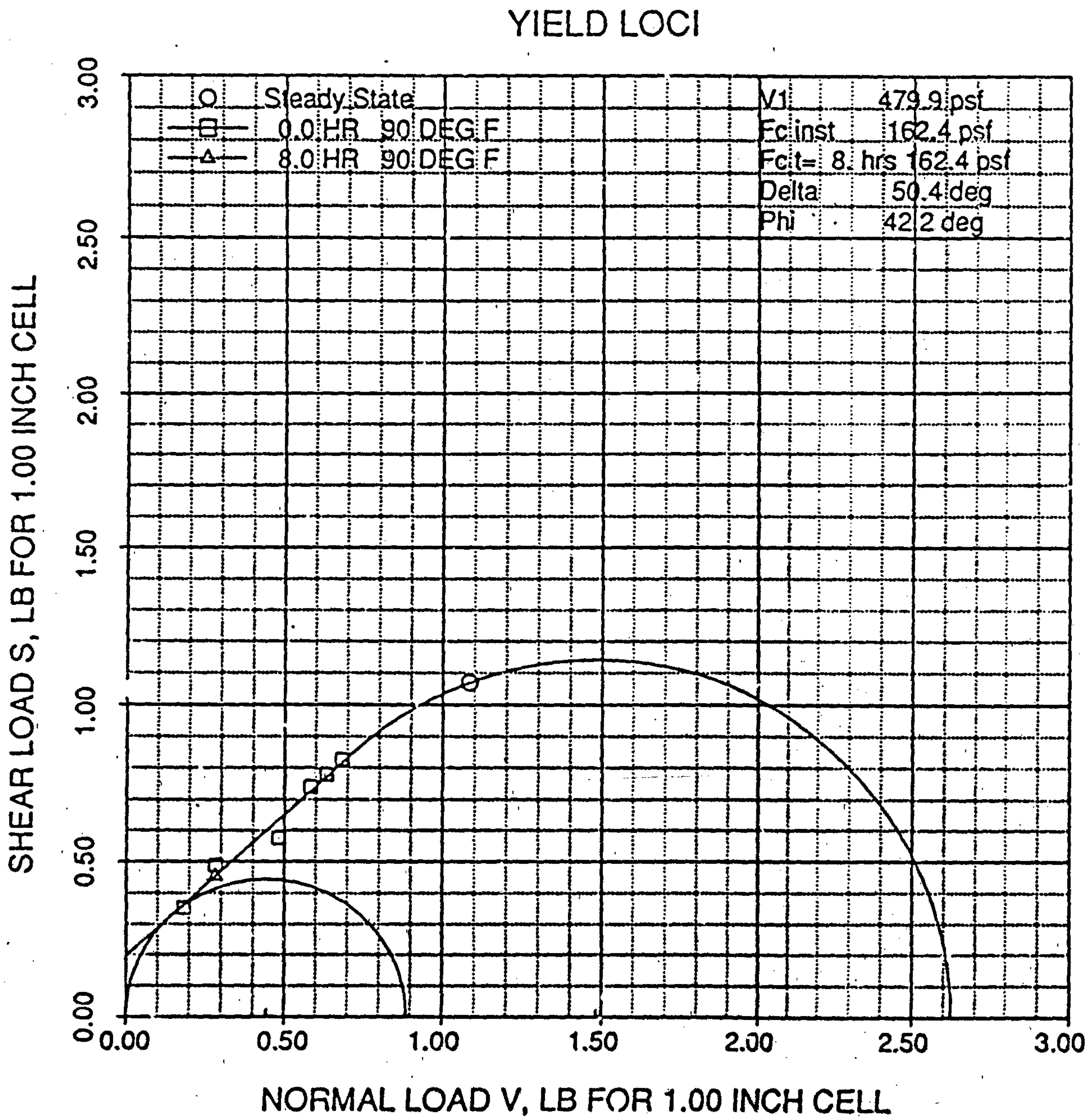
Jenike & Johanson, Inc.

plot10833 lab

BULK MATERIAL; Douse Malathion
PARTICLE SIZE: As Rec'd
MOISTURE % WT: 0.71%

CREATE: 91/05/06
RUN: 91/05/04

JOB#: 912447
ID#: 17169



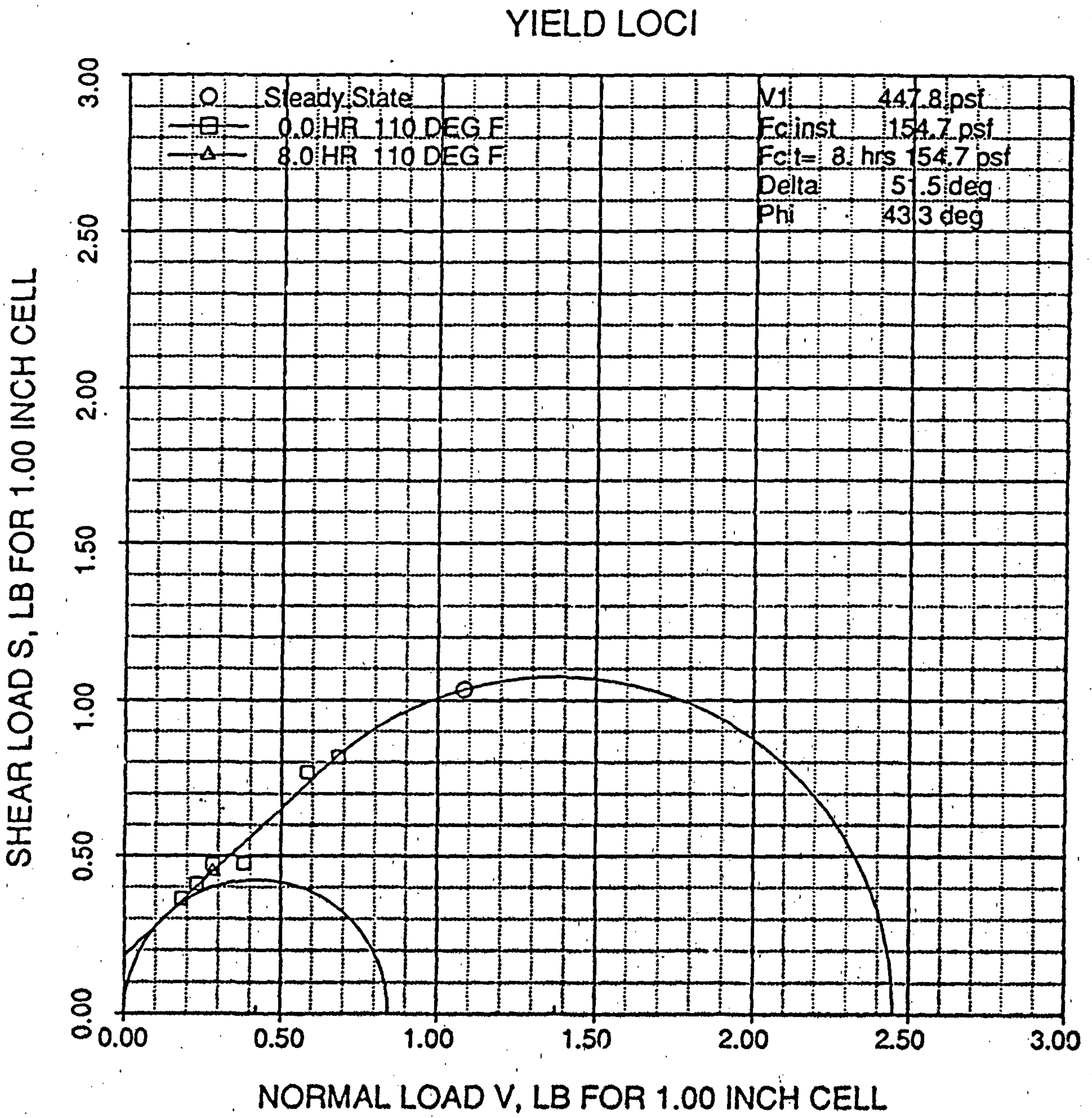
Jenike & Johanson, Inc.

plot10834 lab

BULK MATERIAL: Douse Malathion
PARTICLE SIZE: As Rec'd
MOISTURE % WT: 0.71%

CREATE: 91/05/06
RUN: 91/05/04

JOB#: 912447
ID#: 17170



Jenike & Johanson, Inc.

APPENDIX

SELECTION OF BIN AND FEEDER

Types of Bins

A bin (silo, bunker) generally consists of a vertical cylinder and a sloping, converging hopper.

In the process of selection of a bin, the first step is to decide on the type of bin required. From the standpoint of flow, there are three types: mass flow, funnel flow and expanded flow.

Mass flow bins

In a mass flow bin, the hopper is sufficiently steep and smooth to cause flow of all the solid without stagnant regions whenever any solid is withdrawn.

Mass flow bins, examples of which are shown in Fig. A1, have certain advantages. Flow is uniform and the feed density is practically independent of the head of solid in the bin. This frequently permits the use of volumetric feeders for feed rate control. Since stagnant regions are eliminated, low level indicators work reliably. Even though a solid may segregate at the point of charge into the bin, segregation of the discharge is minimized by the first-in-first-out flow sequence associated with mass flow which enforces the same particle size distribution to exit the hopper as was put into it. This flow sequence also ensures uniform residence time and deaeration of a fine powder.

Mass flow bins are recommended when handling cohesive materials, powders, materials which degrade with time and when segregation needs to be minimized.

Ledges and protrusions are not permitted in a mass flow hopper. In addition the outlet must be fully effective. If the hopper is equipped with a shut-off gate, the gate must not prevent flow of material along the hopper wall. If a feeder is used, it must draw material across the full outlet area. (See "Feeders" below)

Mass flow bins can be used for in-bin blending. Some of the limitations of previous designs have recently been overcome with Jenike & Johanson's patented BINSERT™ bin insert. This device controls the flow pattern of solids in a bin.

Funnel flow bins

Funnel flow occurs when the hopper is not sufficiently steep and smooth to force material to slide along the walls. It also occurs when the outlet of a mass flow bin is not fully effective. Examples of funnel flow bins are shown in Figure A2.

In a funnel flow bin, solid flows toward the outlet through a channel that forms within stagnant material. With a nonfree-flowing solid, this channel expands to a diameter that approximates the largest dimension of the outlet. When the outlet is fully effective, this dimension is its diameter if circular, or the diagonal if it is square or rectangular. The channel will be stable if its diameter is less than the critical rathole diameter.

With a free-flowing solid, the flow channel expands at an angle which depends on the effective angle of friction of the material. The resulting flow channel is generally circular with a diameter in excess of the outlet diameter or diagonal.

When the bin discharge rate is greater than the charge rate, the level of solid within the channel drops causing layers to slough off the top of the stagnant mass and fall into the channel. This spasmodic behavior is detrimental with cohesive solids since the falling solid packs on impact, thereby increasing the chance of arching. With sufficient cohesion sloughing may cease, allowing the channel to empty out completely and form a stable rathole. Aerated solid charged into this empty rathole may overflow the feeder.

When a fluidized powder is charged directly into a funnel flow channel at a sufficiently high rate and is withdrawn at the same time, it has no chance to deaerate. It therefore remains fluidized in the channel and flushes when exiting the bin. A rotary valve is often used under these conditions to contain the material, but a uniform flow rate cannot be ensured because flow into the valve is erratic.

In general funnel flow bins are only suitable for coarse, free-flowing or slightly cohesive, nondegrading solids when segregation is unimportant.

Converting funnel flow bins to mass flow can often be achieved with relatively little expense. It may be done by using the BINSERT™ referred to in the paragraph on blending above.

Expanded flow bins

Examples of expanded flow bins are shown in Figure A3. The lower part of such a bin operates in mass flow while the upper part operates in funnel flow. The mass flow outlet usually requires a smaller feeder than would be the case for a funnel flow bin. The mass flow hopper should expand the flow channel to a diagonal or diameter equal to or greater than the critical rathole diameter. This eliminates the likelihood of ratholing in the funnel flow section.

These bins are used for the storage of large quantities of nondegrading solids. This design is also useful as a modification of existing funnel flow bins to correct erratic flow caused by arching, ratholing or flushing.

The concept can be used with multiple outlets as shown in Fig. A3 (b) where simultaneously flowing mass flow hoppers are placed close enough together to cause a combined flow channel larger than the critical rathole diameter.

With extremely free-flowing solids such as plastic pellets, cement clinker and coarse sand, both funnel flow and expanded flow bins may pulsate. This is caused by the flow pattern suddenly switching from a steady state central channel type flow to a much more extensive secondary flow pattern that may extend to the bin walls. Such a condition may reduce segregation problems, but the shock loads imposed may seriously challenge the structural integrity of the bin.

Feeders

The specified outlet must be fully effective. If flow from the bin is controlled by means of a feeder, the feeder must be so designed as to draw uniformly from the entire cross section of the outlet, a condition which not all feeders satisfy.

This uniformity of draw is especially important when feeding fine powders from slotted outlets. Typical commercial designs tend to draw material either from the front or the back of the slot resulting in a high velocity channel having a diameter of one to two times the width of the outlet. The powder may remain fluidized within this channel and flush on exiting the bin.

To limit high initial loads and starting torque caused by differential settlement between the hopper and the feeder, it is essential that the feeder be either suspended from the bin itself or supported on a flexible frame so as to readily deflect with the bin as solid is added to it. When the feeder is properly designed for uniform flow and when convergence of the hopper extends to the feeder, the effective head EH of solid on the

feeder during flow in a mass flow bin is approximately

$$EH = BP \text{ for a transition hopper} \qquad (1)$$

$$EH = BC/2 \text{ for a conical hopper}$$

See page A5 for definitions of BP and BC.

Initial loads may be several times these values.

Vibrating Equipment

Vibration has two effects: while it tends to break arches that obstruct flow, it also packs the solid in stagnant regions thereby giving it greater strength. In order to allow for this packing, the recommended outlet dimensions at zero time at rest for a P-FACTOR (described on page A6) of 1.5 may be used as an approximation when calculating critical arching dimensions for use with vibrating equipment.

Vibrators are suitable for materials which are free flowing under conditions of continuous flow but cake and gain strength when stored at rest for hours or days. Hoppers for these materials should be equipped with pads for the mounting of external vibrators. Vibrators should be used only to initiate flow and turned off once flow has started.

Fine powders and wet materials tend to pack severely when vibrated; hence, vibrating equipment is generally not recommended for them.

DISCUSSION OF TEST REPORT DATA

In the discussion which follows, each Section of the test report is explained in general terms. Please refer to Figs. A1, A2, and A3 where many of the symbols are shown. The symbols and other terms used in the text are explained in the Glossary of Terms and Symbols on pages A12 to A15. The concepts of gravity flow of solids and examples of application of solids flow data are presented in greater detail in the attached papers.

Section I - Bin Dimensions for Dependable Flow

This section specifies the bin outlet dimensions necessary for dependable flow in both mass flow and funnel flow bins. These dimensions have been calculated on the basis of the frictional and cohesive properties of the solid given in a subsequent part of the report. In all cases, it is assumed that flow takes place only under the action of gravity, i.e. without internal or external assistance.

In general these dimensions are a function of the time the solid remains in storage at rest, its moisture content, temperature, particle size and overpressure, if any, that is applied to it during storage. The P-FACTORs given in the table are ratios of applied compaction pressure to that pressure resulting from gravity flow only. If there are no overpressures present, the critical dimensions for P-FACTOR = 1.0 should be used. If the P-FACTOR is greater than 1.0, it is assumed that overpressures have been exerted on the solid during storage, but are removed when the solid is required to flow. See page A6 to A8.

Mass flow bins have hopper walls which are smooth and steep enough to cause flow along them; hence, stable channels within the material (ratholes) do not develop. Only two dimensions, both of which are shown in Fig. A1, are specified: BC, the minimum outlet diameter for a conical hopper; and BP, the minimum width for a slotted or oval outlet. The length of the slot or oval should be at least three times its width or the end walls must be vertical and smooth for BP to apply.

A funnel flow bin is created whenever the hopper walls are not steep and smooth enough to cause flow along them. Slotted outlets are recommended for these bins unless the material is quite free flowing. To prevent stable arches from forming, the width of the slot must be at least equal to BF. In a funnel flow bin the solid is held up at the walls and flows only within a circular channel whose diameter is approximately equal to the diameter or length of the effective outlet. If this flow channel diameter is less than the critical rathole diameter DF given in the report, a stable rathole is likely to form and the live capacity of the bin will be

essentially only that material which is in the flow channel above the outlet. To prevent stable ratholes from forming, funnel flow bins should be designed with slotted outlets of length at least as long as DF.

In general DF is proportional to the consolidating pressure imposed on the solid during filling of the bin. Hence, in the upper regions of a bin where pressures are low, the critical rathole diameter DF is small and the flow channel diameter may exceed DF. This causes the rathole to be unstable at this point allowing the material to collapse into the stable rathole below. A partial emptying of the bin will result.

Calculation of Effective Head EH

The critical rathole diameter DF is a function of the major consolidating pressure which acts on the solid in the bin. It is convenient to express this pressure in terms of EH, the effective consolidating head of solid in the bin, as follows:

$$EH = [R/(\mu k)]\,[1 - EXP(-\mu k\; H/R)] \quad \text{or} \quad EH = 2R \qquad (2)$$

whichever is larger. The parameters are

- R = hydraulic radius of the cylindrical portion of the bin, i.e. ratio of cross sectional area to circumference.
  - R = D/4 for a circular cylinder of diameter D or a square cylinder of side D.
  - R = W/2 for a long rectangular cylinder of width W.
- μ = tan (PHI-PRIME), coefficient of friction between the stored solid and the cylinder walls (see Section III).
- k = ratio of horizontal to vertical solids pressure. A value of 0.4 is usually acceptable within cylinders.
- H = height of the cylindrical portion of a bin.

Calculation of P-FACTORs

The magnitude of the overpressure factor can be estimated for vibration, impact during charging into the bin, external loading, and fluid flow loading as follows:

Vibration. P-FACTOR = a_y/g or $(1 + a_x/g)$ (3)

whichever is larger, where:

a_x = vertical upward component of acceleration imposed on the solid
a_y = horizontal component of acceleration imposed on the solid
g = gravitational acceleration constant

Impact pressure from fall into a bin. A coarse material compacts as it is charged into a bin under the impact of the falling particles. When the material contains fines and the impact area is close to the outlet, the impact P-FACTOR should be used in the design.

$$\text{P-FACTOR} = (1 + m)\ [w/(A\ B\ \text{GAMMA})] \sqrt{2h/g} \qquad (4)$$

where:

w = weight flow rate into the bin
h = height of fall
m = 0 for a long rectangular outlet
m = 1 for a circular or square outlet
A = area impacted by the falling stream of solids
B = outlet size or bin dimension in the region of impact, i.e. the diameter in a conical hopper or the width in a wedge shaped or transition hopper.
GAMMA = bulk density of solid

External loading. If the solid has been compacted by an external load F - such as the weight of a tractor passing over an outside stockpile - the overpressure factor at the point of application is given by

$$\text{P-FACTOR} = (1 + m)\ F/(A\ B\ \text{GAMMA}) \qquad (5)$$

where:

A = area of load application.

Liquid or gas flow loading. If the solid has been subjected during storage to fluid or gas flow such as may have been imposed by an air blaster, draining of a saturated solid or the flow of air or gas during drying or chemical processing, the overpressure factor is given by

$$\text{P-FACTOR} = 1 + (dp/dx)/(\text{GAMMA}) \qquad (6)$$

where:

dp/dx = the downward (vertical) liquid or gas pressure gradient at the bin outlet.

In any of the above cases, if the overpressure continues to act during the discharge of the solid and is positive downward, the overpressure factor need not be applied. If the downward pressure acts only during discharge, the dimensions given in Section I A for P-FACTOR = 1.0 may be reduced by dividing them by the appropriate P-FACTOR.

When considering the effect of overpressure which acts on a solid during

time of storage at rest, it is not necessary that the overpressure act during the entire time at rest. Soon after an overpressure has been applied, a solid reaches the maximum densification associated with that overpressure. Hence, the critical outlet dimensions will be essentially the same whether the overpressure acts for a short time or continuously during the entire time at rest.

Limits on Bin Sizes

The bin dimensions in part A of this Section I apply to bins of unlimited maximum size. However, some materials will compact in large bins causing large stable arches in the upper part of the hopper while the lower portion may discharge without a problem. This can lead to a very dangerous condition when a large arch is broken high in the hopper. The impact of the falling material may cause structural damage to the bin and possibly tear the hopper from the vertical bin section. If the material is capable of this type of behavior, an additional part B is included which gives the maximum allowable mass flow bin and hopper dimensions.

Often the upper limits on bin size occur only for compaction with time or for significant overpressure conditions. If this is the case, the bin can be designed for an unlimited size provided the critical time and overpressure values are not exceeded during the bin operation.

Section II Bulk Density

The bulk density GAMMA of a material is used in bin load and capacity calculations. Values of bulk density of the sample tested are given in Section II as a function of the effective head of solid EH and the major principal consolidating pressure SIGMA1. The relationship is:

$$\text{SIGMA1} = \text{EH} \times \text{GAMMA} \qquad (7)$$

Within the cylindrical part of a bin, the effective consolidating head EH is given by eq.(2). At the outlet of a mass flow bin, the head is given by eq.(1).

Note that if the sample tested is the fine fraction of a material having a wide range of particle size, inclusion of the coarser particles will usually increase the bulk densities above those given in this section.

Bulk density values have been computed from measured compressibility parameters of the material which are also given in Section II. In general,

all materials have a minimum density GAMMA MINIMUM without fluidization. The relationship between bulk density and consolidating pressure only applies when densities are greater than GAMMA MINIMUM.

Section III Maximum Hopper Angles for Mass-Flow

A solid sliding on a bin wall encounters frictional resistance proportional to the tangent of the wall friction angle PHI-PRIME. This angle generally depends not only on the roughness of the wall but also on the pressure which the solid exerts on the wall. For hard wall surfaces, the friction angle decreases as the solids contact pressure increases. This pressure, which varies with position in the bin, is usually smallest at the outlet.

THETA-C and THETA-P are the recommended maximum hopper wall angles, measured from the vertical, for conical and transition mass flow hoppers, respectively. See Fig. A1. These values have been calculated from the friction tests (wall yield loci) included at the end of the report and are tabulated for a series of widths of oval hoppers and diameters of conical hoppers.

To minimize headroom consider changing the slope of the hopper wall as a function of position. For example, if a conical hopper is to be designed with an outlet diameter of 1 ft and the recommended THETA-C is 14° at 1 ft diameter and 23° at 2 ft and larger diameters, use two conical sections. In the lower section where the diameter varies from 1 ft to 2 ft, use a hopper angle of 14°. Above the 2 ft diameter, use a hopper angle of 23°.

Often, both continuous flow and time friction tests are run on a material. If the solid adheres to the wall with time, the time test results will indicate an increase in friction angles. To overcome this time effect, the hopper walls should be made steeper, as recommended, or other means - such as vibration of the bin walls - should be provided to initiate flow.

Section IV Critical Solids Flow Rate

The maximum rate Q at which a coarse solid (say, 95% plus 1/4 inch) flows out of a mass flow hopper is practically independent of the head of solid and is approximately given by

$$Q = (A \quad GAMMA) \sqrt{B \; g/[2(1 + m) \tan(THETA)]} \qquad (8)$$

where:

A = area of the outlet.
B = diameter or width of the outlet.

THETA = THETA-P for rectangular or oval outlets, or
= THETA-C for circular outlets.

Predicting the flow rate of fine solids is more complicated because their outflow rate is critically affected by the amount of air entrained in the solid.

Two limiting cases may occur: first, the bin may be charged and discharged at such a rapid rate that a large amount of air is entrained within the solid. As a result the solid may flush and flow uncontrollably from the outlet independent of feeder speeds. The prediction of this critical flushing condition requires an extensive two-phase flow calculation using a Jenike & Johanson proprietary computer program and is not a part of this Standard Test Report.

Second, the bin may be filled intermittently with sufficient retention time before discharging to deaerate the solid. As a result there may be a deficiency of air as the solids expand upon discharging. This generally causes a critical flow rate at the outlet which is tabulated in this section as a function of effective head of solid in the bin. Above this critical rate, flow will be nonsteady.

The critical rates are computed on the assumption that there is no air in-flow or out-flow along the height of the bin, that air pressure at the outlet of the bin is the same as at the top of the bin, and that the feeder outlet is not sealed against air in-flow. Should the operating conditions deviate from these assumptions, a controlled rate different from the critical may be possible.

If the tabulated flow rates are smaller than desired, it may be necessary to: use an air permeation system to increase the rate; increase the outlet size; decrease the bin size; or limit the storage time to prevent deaeration of the solid. Jenike & Johanson can analyze the system and make recommendations.

If the specified flow rate from a bin is close to critical values, it is particularly important that the feeder withdraw uniformly across the entire outlet. If this is not done, localized limiting rate effects may occur at the outlet, especially at the ends of a slotted outlet. This may result in pulsating flow from the bin, the development of fast flowing columns and an uncontrolled rate of withdrawal with flushing.

All the above comments apply as well when a gas other than air is used in the bin. The critical property is the viscosity of the gas. The permeability tests run by Jenike & Johanson are done with air at room temperature. When the gas or the temperature is different, the coefficient

of permeability needs to be modified, as discussed below.

Section V Air Permeability Test Results

Values of air permeability are expressed as a function of the bulk density of the solid. These values are used in the calculation of critical flow rates, given in Section IV, and in the design of air permeation systems.

The equation given in this section and the test method are both based on the assumption of laminar flow of gas. This assumption is generally valid for all powders and for most materials which have a significant portion of particles less than 20 mesh in size.

The permeability factor K has the dimension of velocity and is inversely proportional to the viscosity of the gas. The results can be adjusted to elevated temperatures and to other gases by multiplying the constant KO by the ratio of the viscosity of air at room temperature to that of the gas at the temperature in question.

GLOSSARY OF TERMS AND SYMBOLS

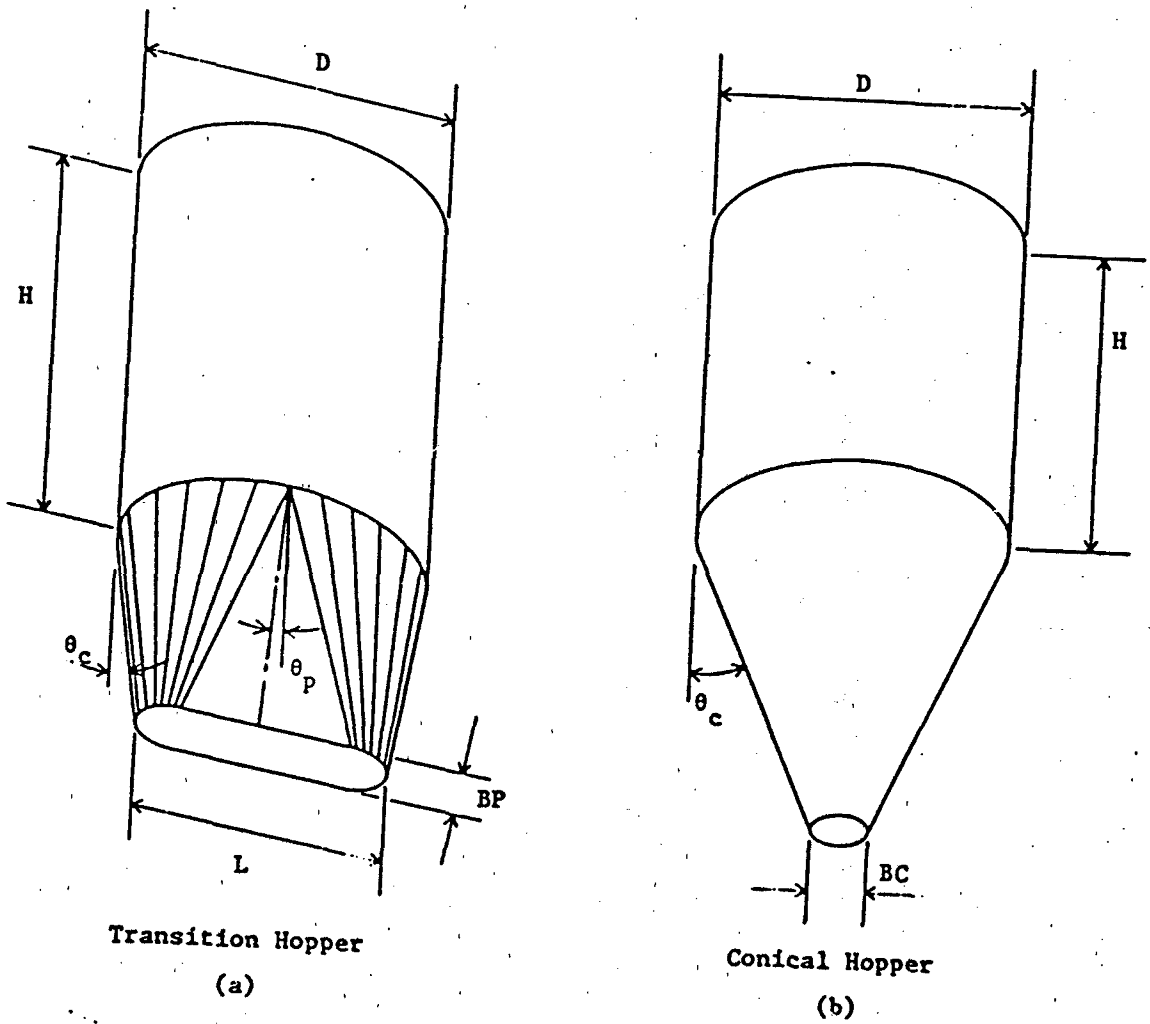
Arching	- a no-flow condition in which material forms a stable arch (dome, bridge) across the bin
Bin	- container for bulk solids with one or more outlets for withdrawal of solids either by gravity alone or by flow-promoting devices which assist gravity
Bunker	- same as bin, often used in reference to storing coal
Cylinder	- vertical part of a bin
Discharger	- device used to enhance material flow from a bin but which is not capable of controlling the rate of withdrawal
Effective head	- convenient way to express consolidating pressure by dividing it by bulk density
Elevator	- same as bin, often used in reference to storing grains
Expanded flow	- flow pattern which is a combination of mass flow and funnel flow
Feeder	- device for controlling the rate of withdrawal of bulk solid from a bin
Flow channel	- space in a bin through which a bulk solid is actually flowing during withdrawal
Flooding & flushing	- conditon where an aerated bulk solid behaves like a fluid and flows uncontrollably through an outlet or feeder
Funnel flow	- flow pattern in which solid flows in a channel formed within stagnant material
Hopper	- converging part of a bin
Mass flow	- flow pattern in which all solid in a bin is in motion whenever any of it is withdrawn

Piping	-	a no-flow condition in which material forms a stable vertical hole within the bin
P-FACTOR	-	the ratio of the applied solids compacting pressure to the solids pressure during steady gravity flow.
Ratholing	-	same as piping
Silo	-	same as bin
A	-	area of impact of falling stream of solids, area over which external load is applied, or area of outlet, ft^2
a_x, a_y	-	vertical and horizontal accelerations respectively, ft/sec^2
B	-	span across a bin at any elevation of the bin, ft
BC	-	minimum diameter of a circular outlet in a mass flow bin, ft
BF	-	minimum width of a rectangular outlet in a funnel flow bin, ft
BP	-	minimum width of an oval outlet in a mass flow bin, ft
D	-	diameter of cylindrical portion of a bin, ft
DF	-	critical piping (ratholing) dimension, ft.
EH	-	effective consolidating head, ft
F	-	force from an external load on material, lb
f_c	-	unconfined compressive strength of a solid, psf
g	-	gravitational constant = 32.2 ft/sec^2
H	-	height of cylinder, ft
h	-	height of fall of material, ft
K	-	permeability factor, ft/sec
k	-	ratio of horizontal to vertical pressure

KO	- permeability constant, ft/sec
L	- length of hopper outlet, ft
m	- parameter equal to 0 for rectangular outlet and equal to 1 for circular or square outlet
p	- liquid or gas pressure, psf
Q	- maximum discharge rate of a coarse solid, lb/sec
R	- hydraulic radius, ft
S	- shearing force applied to a shear cell, lb
V	- normal force applied to a shear cell, lb
W	- width of rectangular bin cylinder, ft
w	- weight flow rate into the bin, lb/sec
x	- vertical coordinate, ft
y	- horizontal coordinate, ft
γ, GAMMA	- bulk density, pcf
δ, DELTA	- effective angle of internal friction of a solid during flow, degrees
θ_c, THETA-C	- maximum recommended angle (from vertical) of conical hoppers and end walls of transition hoppers for mass flow, degrees
θ_p, THETA-P	- maximum recommended angle (from vertical) of side walls of transition hoppers for mass flow, degrees
μ, MU	- tan (PHI-PRIME)
σ, SIGMA	- normal stress applied to a shear cell, psf
σ_1, SIGMA1	- major consolidating pressure, psf
τ, TAU	- shearing stress applied to a shear cell, psf

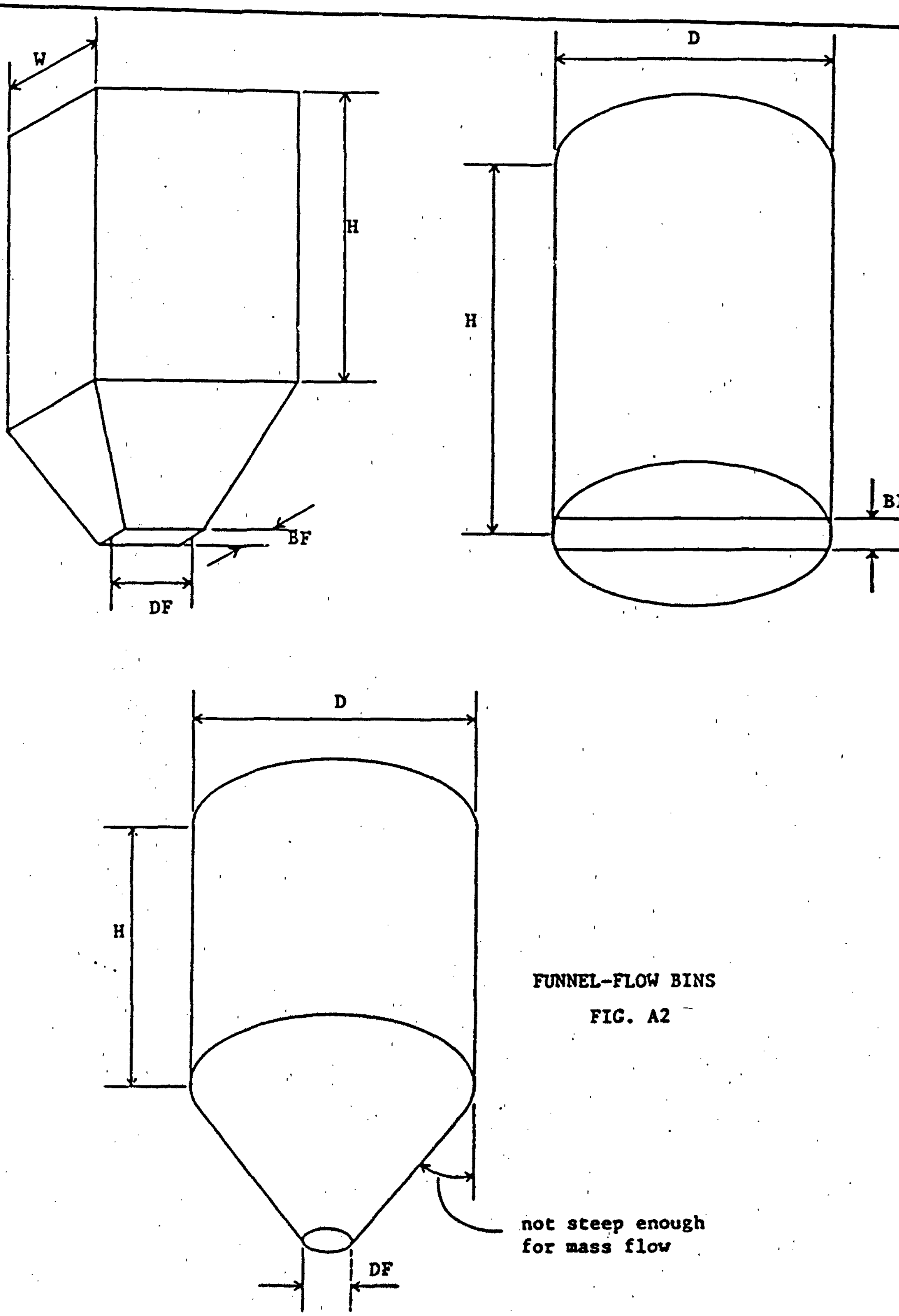
ϕ', PHI-PRIME - kinematic angle of friction between a solid and a wall, degrees

ϕ, PHI - angle of internal friction of a solid in incipient flow, degrees



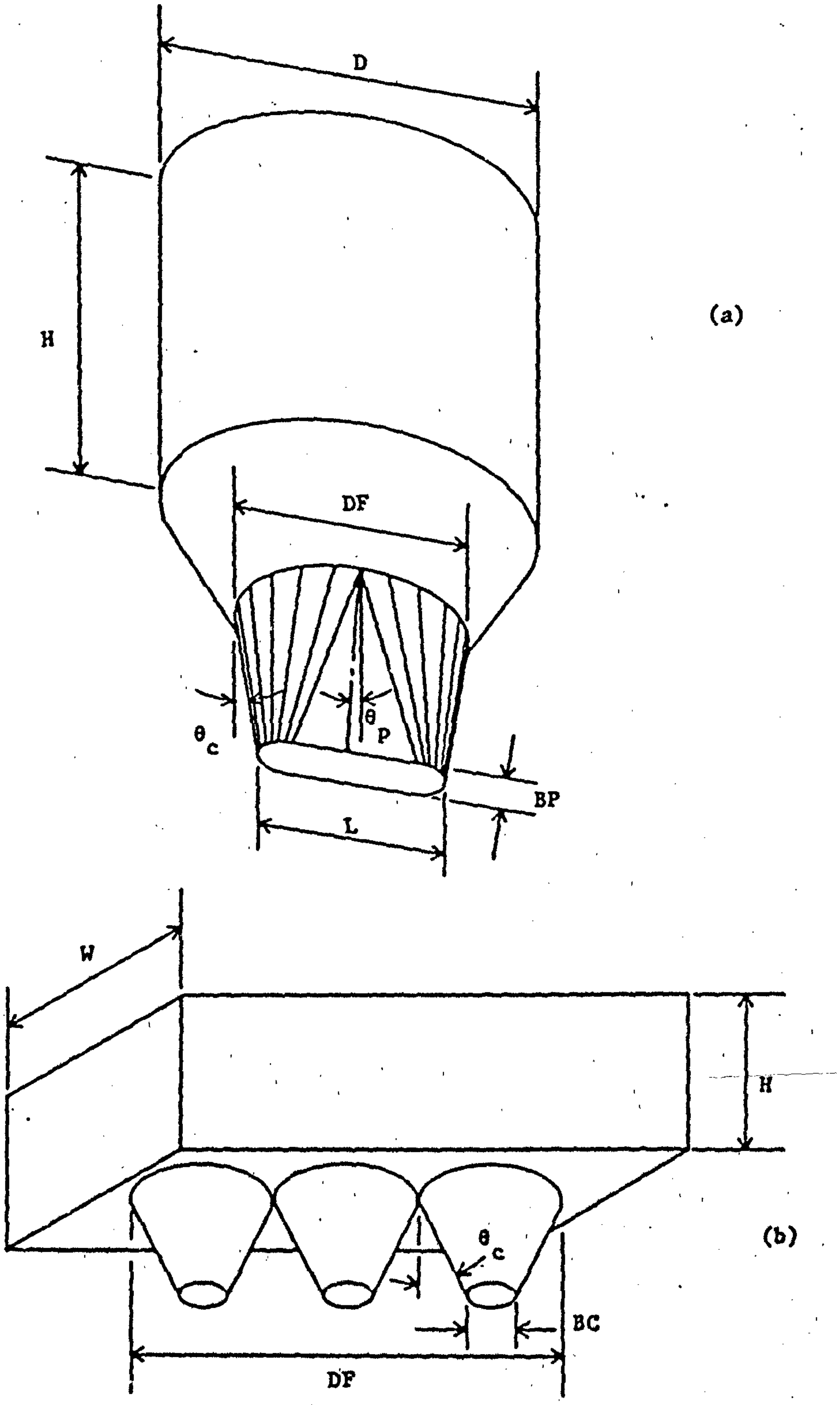
MASS-FLOW BINS

FIG. A1



FUNNEL-FLOW BINS

FIG. A2



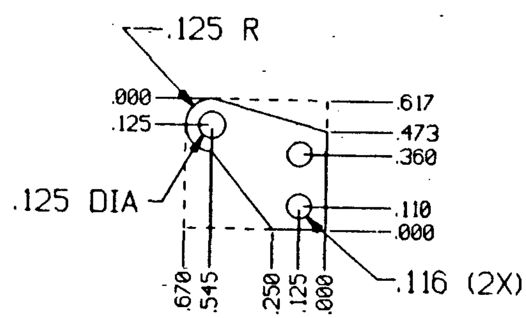
EXPANDED - FLOW BINS

FIG. A3

APPENDIX C: Level II Drawings of the Advanced Prototype

NOTES

1. MATERIAL: ALUMINUM
2. DEBUR ALL EDGES AND HOLES



REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

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TREATMENT	CHECK	
FINISH	DESIGN	
SIMILAR TO / ACT WT. / CALC WT	DESIGN ACTIVITY	
	CUSTOMER	

PART DASH NO.	NEXT	FINAL	NEXT ASSY	USED ON
	QTY REQD PER ASSY		APPLICATION	

CARDINAL SCIENTIFIC, INC.
7594 COMMERCE LANE, CLINTON, MD 20735

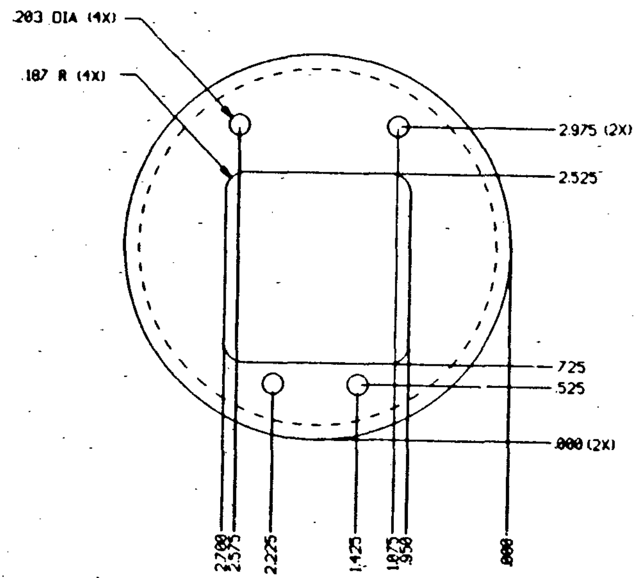
TITLE: BRACE, TRIGGER

SIZE: B | FSCM NO. OFMD6 | DWG NO. CSI-91-2000

SCALE: NONE | RELEASE DATE | SHEET 1 OF 1

NOTES:

1. MATERIAL: PURCHASED PLASTIC LID
2. DEBUR ALL HOLES AND EDGES



REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS ANGULAR
.XX ± .03
.XXX ± .010

DO NOT SCALE DRAWING

TREATMENT

FINISH

SIMILAR TO | ACT WT | CALC WT

PART DASH NO. | NEXT | FINAL | NEXT ASSY | USED ON
QTY REQD PER ASSY | APPLICATION

CONTRACT NO. DAMD17-91-C-1084

DRAWN	JWB	DATE 9/3/91
CHECK		
DESIGN		
DESIGN ACTIVITY		
CUSTOMER		

CARDINAL SCIENTIFIC, INC.
7594 COMMERCE LANE, CLINTON, MD 20735

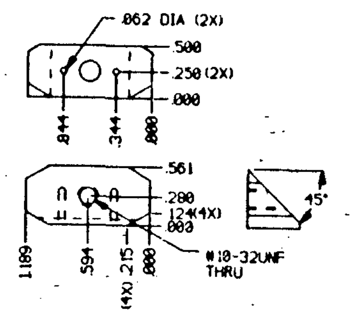
TITLE: CLOSURE, RESEVOIR

SIZE	FSCM NO	DWG NO.
B	OFMD6	CSI-91-2001
SCALE NONE	RELEASE DATE	SHEET 1 OF 1

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

NOTES:

1. MATERIAL: ALUMINUM
2. DEBUR ALL EDGES AND HOLES.



PART DASH NO.	NEXT	FINAL	NEXT ASSY	USED ON	
	QTY REQD PER ASSY		APPLICATION		

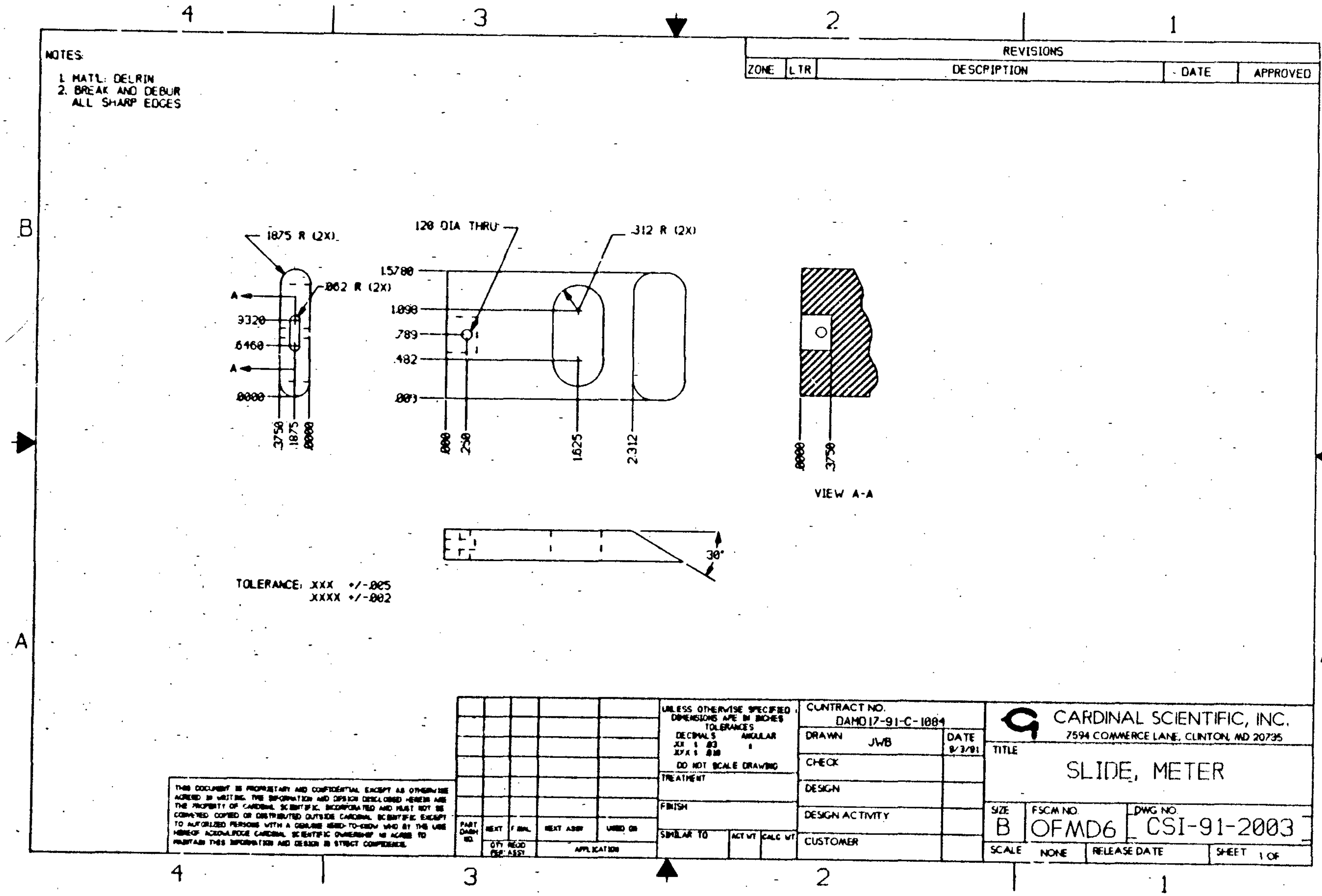
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS .XX ± .03 .XXX ± .010 ANGULAR ±
DO NOT SCALE DRAWING
TREATMENT
FINISH
SIMILAR TO | ACT.WT. | CALC WT

CONTRACT NO. DAMD17-91-C-1084		
DRAWN	JWB	DATE 8/3/91
CHECK		
DESIGN		
DESIGN ACTIVITY		
CUSTOMER		

CARDINAL SCIENTIFIC, INC.
7594 COMMERCE LANE, CLINTON, MD 20735

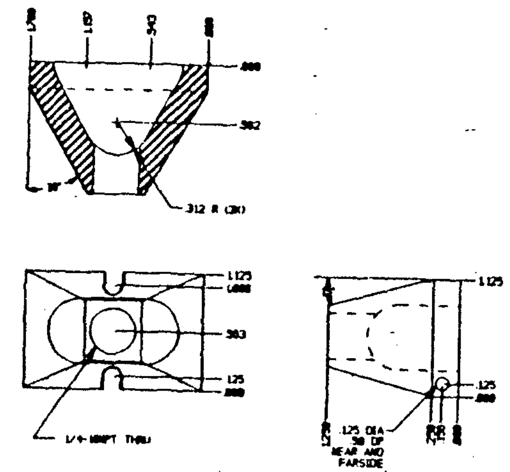
TITLE
PLOW, POWDER

SIZE	FSCM NO.	DWG NO.
B	OFMD6	CSI-91-2002
SCALE NONE	RELEASE DATE	SHEET 1 OF


NOTES:
1. MATL: DELRIN
2. BREAK AND DEBUR ALL SHARP EDGES
.1875 R (2X)
.062 R (2X)
.9320
.6460
.0000
.3750
.1875
.0000
120 DIA THRU
.312 R (2X)
1.5780
1.098
.789
.482
.003
.000
.250
1.625
2.312
.0000
.3750
VIEW A-A
30°
TOLERANCE: XXX +/-.005
XXXX +/-.002
REVISIONS
ZONE
LTR
DESCPIPTION
DATE
APPROVED
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS
ANGULAR
DO NOT SCALE DRAWING
TREATMENT
FINISH
SIMILAR TO
ACT WT
CALC WT
CONTRACT NO.
DAMD17-91-C-1084
DRAWN
JWB
DATE
9/3/91
CHECK
DESIGN
DESIGN ACTIVITY
CUSTOMER
CARDINAL SCIENTIFIC, INC.
7594 COMMERCE LANE, CLINTON, MD 20735
TITLE
SLIDE, METER
SIZE
B
FSCM NO.
OFMD6
DWG NO.
CSI-91-2003
SCALE
NONE
RELEASE DATE
SHEET
1 OF
PART DASH NO.
NEXT
FINAL
NEXT ASSY
USED ON
QTY REQD PER ASSY
APPLICATION

NOTES:

1. MATERIAL: ALUMINUM
2. DEBUR ALL EDGES AND HOLES



REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS .XX ± .03 .XXX ± .010
ANGULAR ±
DO NOT SCALE DRAWING

TREATMENT

FINISH

SIMILAR TO | ACT WT | CALC WT

PART DASH NO. | NEXT FINAL | NEXT ASSY | USED ON | QTY REQD PER ASSY | APPLICATION

CONTRACT NO. DAMD17-91-C-1084

DRAWN JWB | DATE 9/3/91

CHECK

DESIGN

DESIGN ACTIVITY

CUSTOMER

CARDINAL SCIENTIFIC, INC.
7594 COMMERCE LANE, CLINTON, MD 20735

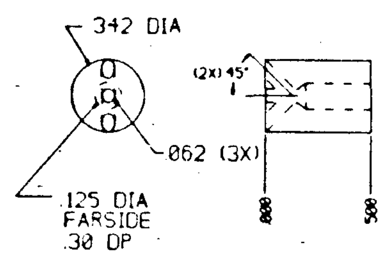
TITLE NOZZLE, EXIT

SIZE B | FSCM NO. OFMD6 | DWG NO. CSI-91-2004

SCALE NONE | RELEASE DATE | SHEET 1 OF 1

NOTES:

1. MATERIAL: BRASS
2. DEBUR ALL EDGES AND HOLES



REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS .XX ± .03 .XXX ± .010 ANGULAR ± 1
DO NOT SCALE DRAWING

TREATMENT

FINISH

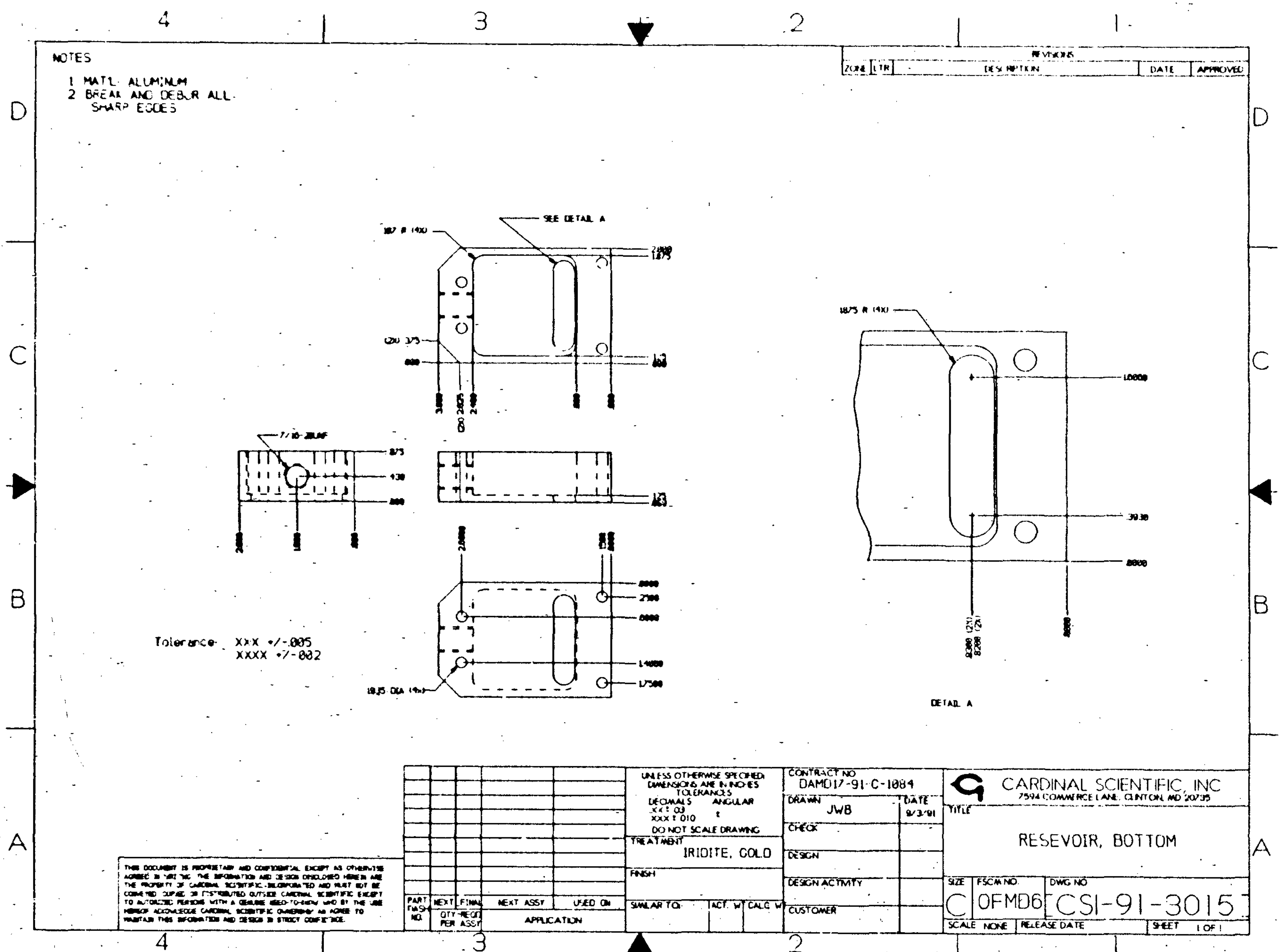
CONTRACT NO. DAMD17-91-C-1084	
DRAWN JWB	DATE 4/3/91
CHECK	
DESIGN	
DESIGN ACTIVITY	
CUSTOMER	

CARDINAL SCIENTIFIC, INC.
7594 COMMERCE LANE, CLINTON, MD 20735

TITLE: NOZZLE, FLUIDIZING

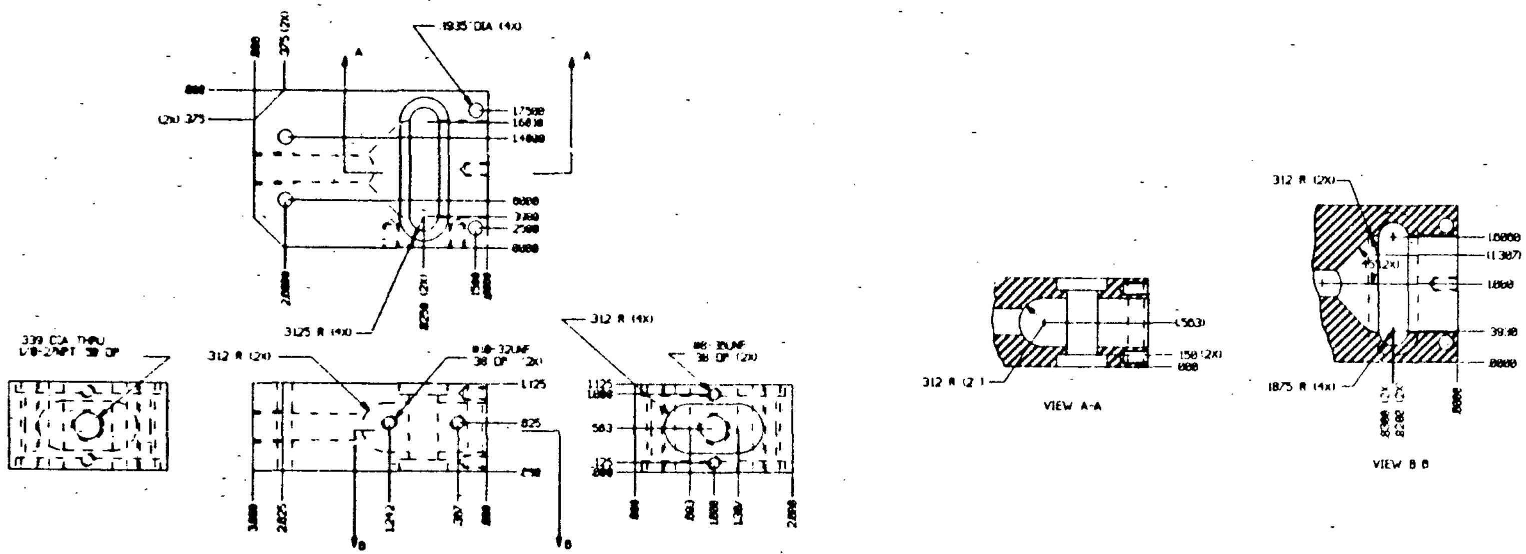
SIZE	FSCM NO	DWG NO
B	OFMD6	CSI-91-2005

SCALE	NONE	RELEASE DATE		SHEET	1 OF 1


NOTES
1 MAT'L: ALUMINUM
2 BREAK AND DEBUR ALL SHARP EDGES
REVISIONS
ZONE LTR DESCRIPTION DATE APPROVED
SEE DETAIL A
187 R (4X)
(2X) .375
1875 R (4X)
7/16-20UNF
.1935 DIA (4X)
DETAIL A
Tolerance: XXX +/-.005
XXXX +/-.002
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS ANGULAR
.XX ± .03
.XXX ± .010
DO NOT SCALE DRAWING
TREATMENT IRIDITE, GOLD
FINISH
SIMILAR TO ACT. WT CALC WT
CONTRACT NO DAMD17-91-C-1084
DRAWN JWB DATE 9/3/91
CHECK
DESIGN
DESIGN ACTIVITY
CUSTOMER
CARDINAL SCIENTIFIC, INC
7594 COMMERCE LANE, CLINTON, MD 20735
TITLE RESEVOIR, BOTTOM
SIZE C FSCM NO. 0FMD6 DWG NO CSI-91-3015
SCALE NONE RELEASE DATE SHEET 1 OF 1
PART DASH NO. NEXT FINAL QTY REQD PER ASSY NEXT ASSY USED ON APPLICATION

NOTES:

1. MATTE ALUMINUM
2. BREAK AND DEBUR ALL SHARP EDGES



TOLERANCE .XXX +/-.005
.XXXX +/-.002

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES TOLERANCES DECIMALS .XX ±.03 .XXX ±.010 ANGULAR ± DO NOT SCALE DRAWING	CONTRACT NO DAMD17-91-C-1084
TREATMENT IRIDITE,GOLD	DRAWN JWB DATE 9/3/91
FINISH	CHECK
SIMILAR TO	ACT WT	CALC WT	DESIGN
	DESIGN ACTIVITY
	CUSTOMER

CARDINAL SCIENTIFIC, INC.
7594 COMMERCE LANE CLINTON, MD 20735

TITLE DISPENSE PORT

SIZE C | FSCM NO 0FMD6 | DWG NO CSI-91-3016
SCALE NONE | RELEASE DATE | SHEET 1 OF 1

PART DASH NO.	NEXT	FINAL	NEXT ASSY	USED ON
	QTY REQD PER ASSY		APPLICATION	

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

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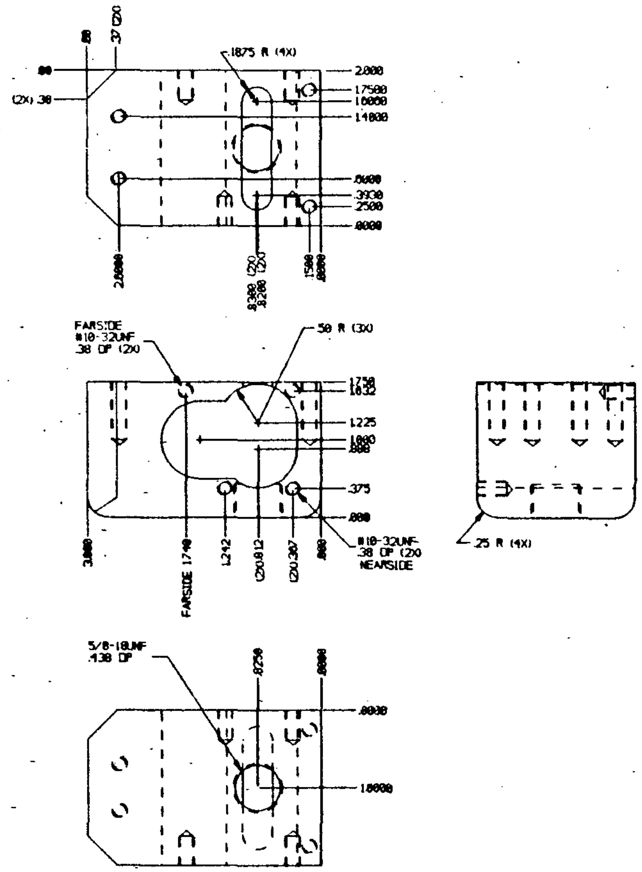
NOTES:
1. MATERIAL: ALUMINUM
2. DEBUR ALL EDGES AND HOLES



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES TOLERANCES DECIMALS .XX ± .03 .XXX ± .010 ANGULAR ±	CONTRACT NO. DAMD17-91-C-1084
DO NOT SCALE DRAWING	DRAWN JWB / DATE 9/3/91
TREATMENT IRIDITE, GOLD	CHECK
FINISH	DESIGN
SIMILAR TO: / ACT. WT / CALC WT	DESIGN ACTIVITY
	CUSTOMER

CARDINAL SCIENTIFIC, INC.
7594 COMMERCE LANE, CLINTON, MD 20735

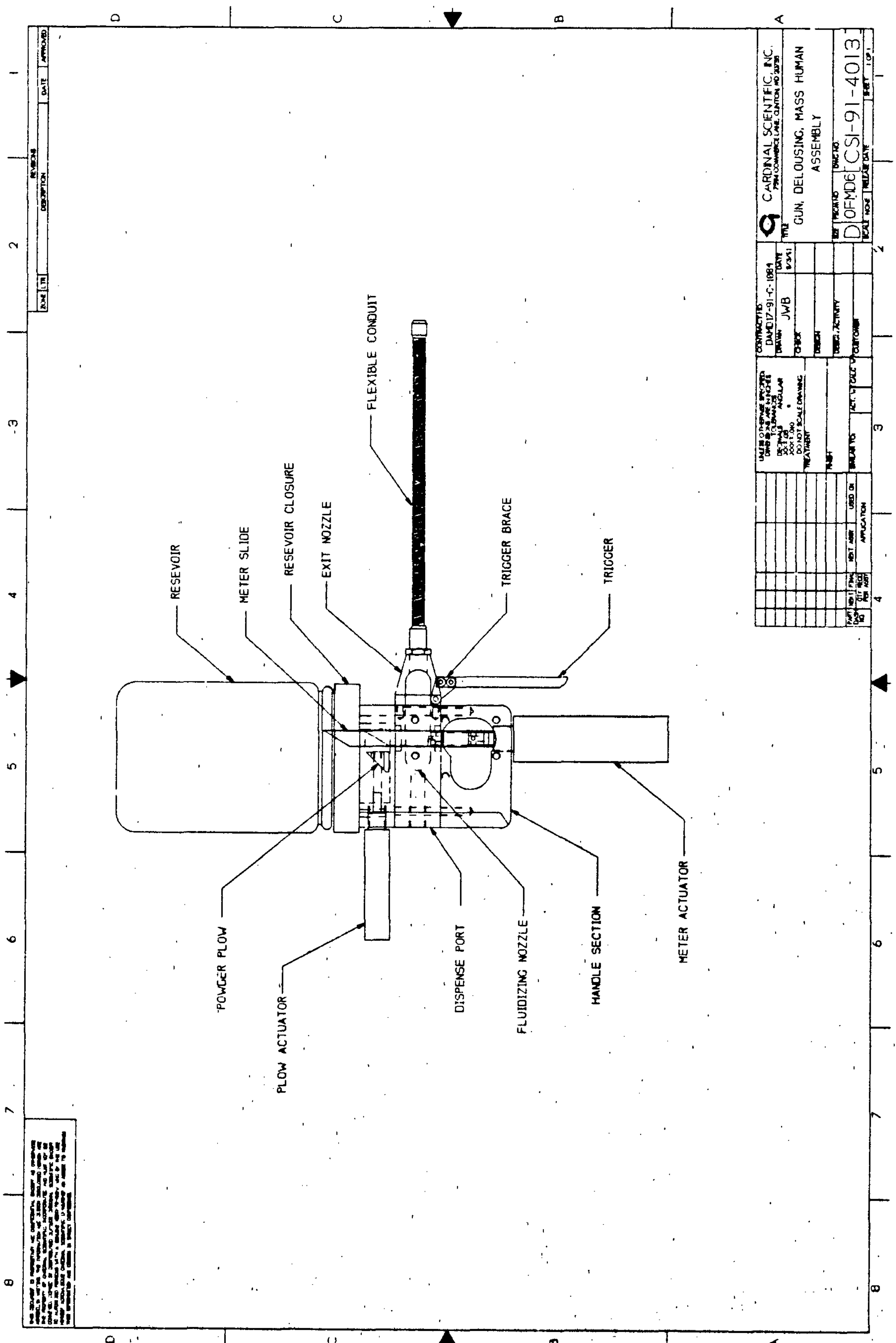
TITLE: HANDLE SECTION

SIZE	FSCM NO.	DWG NO.
C	0FMD6	CSI-91-3017

SCALE NONE | RELEASE DATE | SHEET 1 OF

PART DASH NO.	NEXT	FINAL	NEXT ASSY	USED ON
	QTY REQ'D PER ASSY		APPLICATION	

ZONE	LTR	DESCRIPTION	DATE	APPROVED



FLEXIBLE CONDUIT
RESEVOIR
METER SLIDE
RESEVOIR CLOSURE
EXIT NOZZLE
TRIGGER BRACE
TRIGGER
POWGER PLOW
PLOW ACTUATOR
DISPENSE PORT
FLUIDIZING NOZZLE
HANDLE SECTION
METER ACTUATOR
CARDINAL SCIENTIFIC, INC.
GUN, DELOUSING, MASS HUMAN
ASSEMBLY
DAMD17-91-C-1084
JWB
D
OFMDE
CSI-91-4013

APPENDIX D: Advanced Prototype Assembly/Disassembly Maintenance Instructions

Assembly/Disassembly Maintenance Instructions

O-ring Specification: Buna-N, 216

1. Cycle gun and hold trigger for 10 to 20 seconds.

2. Disconnect air supply from gun

3. Unscrew reservoir jar from gun

4. Squeeze gun trigger with right hand; with left thumb push METER SLIDE (CSI-91-2002) down until it bottoms out.

5. Unscrew two (2) socket head cap screws (#10-32, .25"LG) form the side of the DISPENSE PORT (CSI-91-3016). These screws retain a mini valve. Allow the valve and bracket to be supported by the tubing only.

6. Unscrew four (4) socket head cap screws (#10-32, .25"LG) from RESERVOIR CLOSURE (CSI-91-2001).

7. While holding the METER SLIDE in place slide the RESERVOIR BOTTOM (CSI-91-3015) off the slide, exposing the upper O-ring in the top of the DISPENSE PORT. Allow all tubing to remain in place for reassembly.

8. Inspect the upper O-ring for powder accumulation, abrasion and wear. Replace if necessary.

9. Again while holding the METER SLIDE in place slide the DISPENSE PORT off the slide. Role the DISPENSE PORT 180°, exposing the lower O-ring.

10. Inspect the lower O-ring for powder accumulation, abrasion and wear. Replace if necessary.

11. To reassemble, repeat steps 2 through 7 and 9 in reverse order.